

Tamthai, Bunliang

1943. The nuclear pattern of the non-tectal portions of the mid-brain and isthmus in the mink. (From a series of papers entitled: The mammalian midbrain and isthmus regions, by G. Carl Huber et al.).

J. Comp. Neur., v. 78, no. 3, June.

Anatomy { nervous system
 { comparative

Mink



THE NUCLEAR PATTERN OF THE NON-TECTAL PORTIONS OF THE MIDBRAIN AND ISTHMUS IN THE MINK

BUNLIANG TAMTHAI¹

Department of Anatomy, University of Michigan

ELEVEN PLATES (ELEVEN FIGURES)

INTRODUCTION

The material used in the preparation of this paper on the brain of the mink (*Mustela vison*) is a part of the Huber Neurological Collection and consists of the brain of the mink cut serially in transverse sections and stained by the Huber modification of the toluidin blue method. The descriptions of each nuclear group are supplemented by reference to the pertinent literature. Photomicrographs have been used for illustrations.

For the generous grant which made possible this research the writer wishes to express grateful acknowledgment to the Horace H. Rackham School of Graduate Studies of the University of Michigan. He also wishes to express his sincerest gratitude and indebtedness to Prof. Elizabeth Crosby. The author would also like to take this opportunity of expressing his thanks to Prof. C. Judson Herrick in appreciation of his suggestions and inspiring criticism during the course of the work.

THE PERIVENTRICULAR GROUPS

General areas of periventricular gray

Under this general heading the neuron masses immediately surrounding the cerebral aqueduct will be considered. According to their different locations, they may be placed in three subdivisions — pars dorsalis, pars lateralis and pars ventralis (figs. 3 to 8). This

¹ A dissertation submitted in partial fulfillment of the requirements for the degree of doctor of philosophy.

mesencephalic periventricular gray extends from a plane passing through the upper border of the pons to a level through the posterior commissure and the caudal part of the mammillary body. Rostrally, pars dorsalis appears caudal to the posterior commissure, and pars lateralis and pars ventralis replace the diencephalic-periventricular gray. Pars dorsalis forms the periventricular layers of the optic tectum. Caudally, pars dorsalis and the dorsal part of pars lateralis blend with the neurons of the nucleus of the inferior colliculus without sharp separation; the ventral part of pars lateralis and pars ventralis disappear at the level of the anterior medullary velum by fading into the central gray of the fourth ventricle. Rostrally, the medial portion of the dorsal nucleus of the posterior commissure differentiates from pars lateralis. In pars ventralis, the following nuclei have been observed: the eye-muscle nuclei including the oculomotor and the trochlear nuclei, the laterodorsal tegmental nucleus, the dorsal nucleus of the raphé, the dorsal tegmental nucleus and the nucleus of Darkschewitsch.

Nuclear groups associated with posterior commissure

The nucleus of the posterior commissure shows certain secondary subdivisions, the most outstanding of which are the magnocellular, the intracommissural and the central subcommissural portions. The nucleus of the posterior commissure is represented by two small, indistinct cell groups of irregular outlines. These two groups, the medial and the lateral, or central subcommissural portion or magnocellular part, are not clearly separated from each other. They occupy a position lateral to the deeper portion of pars lateralis of the periventricular gray (figs. 3 to 5) and extend from a plane through the rostral third of the chief oculomotor nucleus to the rostral part of the posterior commissure. At both poles they disappear gradually by fading into the surrounding subtectal gray. They correspond in general to the nucleus of the posterior commissure of Rioch ('29 a). The neurons constituting the medial group of this nucleus are small and multipolar with relatively large, indistinct nuclei, prominent nucleoli and very fine Nissl granules. They are mostly triangular in shape. In the more lateral portions these smaller cells are intermingled with larger neurons of a tegmental type—the presence of which has given the name pars magnocellularis to this portion.

Groups of cells intercalated among the fibers of the posterior commissure near pars dorsalis of the periventricular gray constitute an intracommissural portion of the nucleus of the commissure (figs. 4, 5). The cells of this nucleus are of the same type as the smaller cells in the pars magnocellularis with which the intracommissural portion is

continuous laterally. This intracommissural portion is indistinct and inconstant and has a very short extent, blending with the subtecal gray surrounding it caudally and frontally. In its course it gradually approaches the midline as it is traced rostrocaudally, but the nuclei of the two sides do not meet each other at any level, as Brown ('43) found to be the case in the dog but not in the cat.

Nucleus of Darkschewitsch

The nuclear mass termed the nucleus of Darkschewitsch by Ramón y Cajal ('09-'11), and usually so designated in the literature, although it may not be the nucleus so described by the man whose name it bears, corresponds to nucleus accessorius medialis of Darkschewitsch by Zeri (1895). It appears at the level of the commissure and lies in pars ventralis of the periventricular gray but in a close relationship to the interstitial nucleus of the medial longitudinal fasciculus (figs. 2, 3). At first it is located dorsomedial to the latter and then dorsal to it as traced caudorostrally. It is ventromedial to the nucleus of the posterior commissure and dorsolateral to the oculomotor nucleus. In spite of its close relationship to the interstitial nucleus of the medial longitudinal fasciculus, as a whole it can be differentiated from the latter, not only by its periventricular position, but also by its shorter length, smaller size and less conspicuous outline. The shape of the nucleus is somewhat round with irregular and indistinct boundaries. Rostrally and caudally, it fades into the periventricular gray without sharp demarcation.

This nucleus has been regarded by Perlia (1889), Tsuchida ('06) and Mingazzini ('28) as giving rise to oculomotor fibers. Such a distribution of its neuraxes has been denied by various observers (von Kölliker, 1896; Obersteiner, '01; Ramón y Cajal, '11; and others). The majority of workers have stated that a certain per cent of its neuraxes enter the posterior commissure, decussate there, and pass to the medial longitudinal fasciculus of the other side. Possibly the nucleus plays a rôle in the bilateral coordination of eye-muscle movements (Ariëns Kappers, Huber and Crosby, '36). This nuclear mass is composed of scattered, small to medium-sized, multipolar neurons with triangular and fusiform shapes.

Eye-muscle nuclei

Oculomotor complex. The oculomotor complex may best be considered by reference to the component parts of the cell group. The chief oculomotor nucleus corresponds to the gray mass which Le Gros Clark ('26) called the lateral oculomotor nucleus. It occupies a

position directly dorsomedial and medial to the medial longitudinal fasciculus on either side of the midline (figs. 4, 5). It extends from a plane through the rostral end of the inferior colliculus to the level of the caudal part of the mammillary body. As it is traced caudo-rostrally, the number of cells gradually increases and there is some tendency for the gray to fuse across the midline with its fellow of the opposite side (fig. 6). In about the rostral one-third of the nucleus, the cells begin to diminish and then finally disappear at the level of the caudal end of the mammillary body. The chief oculomotor nucleus can be more or less subdivided, though not sharply separated, into a dorsal or dorsolateral nucleus and a ventral or ventromedial nucleus (fig. 5). Dorsal or dorsolateral and ventral or ventromedial oculomotor nuclei are present in nearly all mammals. In the material available for study, the mink presents a longer ventromedial portion continuing throughout the entire extent of the chief oculomotor nucleus. This portion occupies a position medial to the medial longitudinal fasciculus on either side of the raphé (figs. 3 to 5). The ventromedial nuclei of the two sides approach each other at the midline and a median cell group, the forerunner of the central nucleus of Perlia, is formed in the midportions of the nucleus (fig. 6). The two nuclei are distinctly separated from each other, caudal and rostral to the level of the fusion. The median cell group corresponds to that which Le Gros Clark ('26) described as the paramedian nucleus.

The dorsolateral nucleus of the chief oculomotor complex is more or less circular in outline. It overlies the ventral nucleus and is dorsomedial to the medial longitudinal fasciculus (fig. 5). It is shorter than the ventral nucleus and commences slightly rostral to the caudal pole of the latter and terminates frontally by merging with it. In the mink, no further subdivisions are identifiable.

The cells of the chief oculomotor complex are large, multipolar neurons with large nuclei and distinct Nissl granules and nucleoli. They are typical efferent neurons. The central caudal nucleus, which Tsuchida ('06) and Le Gros Clark ('26) had described, was not found in the mink. In the material studied, the chief oculomotor nucleus is not directly continuous with the trochlear nucleus (fig. 7). There is quite a definite interval, extending over three sections, in which there are no neurons.

Close to the midline, in relation to the frontal end of the dorsomedial aspect of the chief oculomotor nuclei and extending rostral to the latter, is a group of small cells which has been called the Edinger-Westphal nucleus. The nuclei of the two sides are fused into a single nuclear mass across the midline for the rostral half of the nuclei (fig. 4) but are different from each other in the caudal half (fig. 5). These neurons may be described as an unpaired nucleus with two

caudally projecting extensions. This does not entirely agree with Panegrossi ('04) and Brouwer ('18) who stated that a paired Edinger-Westphal nucleus is found only in the monkey and in man. It does agree, however, with Brown's ('43) account of the condition in the dog.

The cells of the Edinger-Westphal nucleus are multipolar and oval or triangular in outline. They are about half the size of the cells of the chief oculomotor complex. They have relatively large nuclei with fine Nissl granules. This nucleus is not well developed in the mink. It has a short extent. Directly in front of the Edinger-Westphal nucleus an elongated cell mass is observed. This is an unpaired structure, though it looks like the fusion of the nuclear gray of the two sides. This nuclear mass probably corresponds to what Panegrossi ('04) termed nucleus medianus anterior (fig. 2). Brouwer ('18) and Le Gros Clark ('26) described this nucleus as a part of the Edinger-Westphal nucleus (rostral Edinger-Westphal nucleus). In the mink, although it is found directly continuous with the latter, cells of the two groups can be differentiated from each other. Neurons of nucleus medianus anterior are smaller and more elongated. Most of them are of spindle or fusiform shape with relatively large nuclei. Their Nissl granules are obvious. As a whole, this nucleus has a greater length than does the Edinger-Westphal nucleus. It extends from the frontal end of the Edinger-Westphal nucleus to a plane through the caudal end of the mammillary body. In its course caudofrontally, the nucleus shifts ventralward from a position ventral to the central gray to a place midway between the cerebral aqueduct and the interpeduncular fossa (fig. 2). There is no agreement that this nucleus gives origin to root fibers. Frank ('21) supposed it to be concerned with the Edinger-Westphal nucleus in forming a midbrain center for convergence.

Nucleus dorsocentralis posterior, an unpaired nuclear mass of Panegrossi (1898, quoted from Castaldi, '24), is not found in this material. Panegrossi described it as a very small nucleus lying between the caudal tip of nucleus medianus anterior and in front of the central nucleus of Perlia. The subfascicular nucleus of the oculomotor nerve of Frank ('21) is described as part of the annular nucleus of the medial longitudinal fasciculus in this paper (see below).

Trochlear gray. As seen in cross section material, the trochlear nucleus bears a close resemblance to the oculomotor gray. It occupies a position below the aqueduct at the level of the inferior colliculus, directly dorsolateral to the medial longitudinal fasciculus and partly embedded within this bundle (fig. 8). It is behind and slightly lateral to the plane of the chief oculomotor nucleus. In the horse, the trochlear gray is ventral to the medial longitudinal fasciculus (Tsuchida, '06 and Gillilan, '43 b, fig. 22). Rostrally, there is a small gap between the frontal end of the trochlear gray and the caudal end of the oculo-

motor complex. The shape of the nucleus is somewhat more nearly circular than that of the oculomotor gray and, on the whole, is smaller and of shorter extent.

The neurons constituting the trochlear nucleus are similar to those of the chief oculomotor complex. They are large and multipolar with distinct Nissl granules, being typical somatic efferent neurons. A small group of tiny cells lying in the ventral part of the periventricular gray, dorsal to the medial longitudinal fasciculus at the level of the trochlear decussation, was described by Westphal (1887), and confirmed by Obersteiner in the same year, as the Westphal or the posterior trochlear nucleus; it is probably a part of pars lateralis of the dorsal nucleus of the raphé in the mink.

Another gray mass, noted by Tsuchida ('06) and described by van Valkenberg ('12) as the posterior trochlear nucleus, if present, lies caudal to the principal trochlear nucleus. It has not been found in the material studied.

Dorsal nucleus of raphé

The dorsal nucleus of the raphé is one of the obvious elements of the ventral periventricular gray in the caudal half of the midbrain (figs. 7 to 8). It is composed of two parts—pars lateralis and pars centralis. Pars centralis is an elongated nuclear mass (figs. 7 to 8) situated in the midline throughout the caudal part of the midbrain and upper pontine levels. Its ventral half extends between the two medial longitudinal fasciculi; its dorsal half is bordered on either side by pars lateralis of the nuclear complex. The dorsal, intermediate and ventral parts of pars centralis, which have been described in some animals, could not be clearly differentiated in the material studied. Pars lateralis (figs. 7 to 8) is represented by circular cell masses bilaterally situated on either side of the central portion, dorsal and dorsolateral to the medial longitudinal fasciculus. Each mass has been called a supratrochlear nucleus (Stengel, '24).

Pars centralis extends from the upper pons region to about the level of the middle of the trochlear nucleus. Pars lateralis, however, is shorter in extent than pars centralis. It begins caudally in planes through the rostral end of substantia nigra and terminates frontally at a level through the caudal tip of the chief oculomotor complex. Both pars centralis and pars lateralis merge into the surrounding gray frontally and caudally without distinct lines of demarcation.

The neurons of the dorsal nucleus of the raphé are of the same type in both portions. They are large to medium-sized, multipolar triangular or spindle-shaped cells intensely stained in the toluidin

blue preparations. They have relatively large nuclei with distinct nucleoli. Fine Nissl granules are distributed throughout their cytoplasm.

Laterodorsal tegmental nucleus

Directly dorsolateral to the dorsal tegmental nucleus at the caudal levels of the midbrain and in the aqueduct region, a group of neurons has been described as nucleus laterodorsalis tegmenti (Castaldi, '26). This group is in the lateral part of the central gray, ventromedial to the nucleus of the mesencephalic root of the trigeminal nerve (figs. 9, 10). It has an irregular outline with indistinct boundaries. Frontally, it ends at the level of the beginning of the cerebral aqueduct by merging into the periventricular gray. Caudally, it disappears about the same level as does the dorsal tegmental nucleus—that is, in the upper pons region—by fading into the central gray. At levels through the frontal end of nucleus medialis profundus its cells come into a very close relationship or even intermingle with the cells of the nucleus of locus coeruleus (fig. 10), which may be regarded as a special differentiation of the lateral part of nucleus laterodorsalis tegmenti.

The laterodorsal tegmental nucleus is composed of small and medium-sized neurons with various shapes from irregular and spindle to oval and triangular. Their nuclei and Nissl granules are indistinct. Castaldi ('26) discussed the possible relations of this nucleus to the trigeminal nerve and concluded that, although it might receive some fibers or possibly collaterals of the mesencephalic root of the trigeminal, it could not be considered a true and proper sensory nucleus of this nerve.

Nucleus of locus coeruleus has been considered in a number of contributions dealing with the nucleus of the mesencephalic root of V. There still appears to be a difference of opinion in regard to both its cell types and its relations to this nerve. The human locus coeruleus has been described by Ranson ('40, and elsewhere) as a shallow groove, faint blue in color, extending from the superior fovea in the floor of the fourth ventricle to the cerebral aqueduct. Beneath locus coeruleus, he stated, are pigmented nerve cells composing substantia ferruginea. Locus coeruleus itself is sometimes called substantia ferruginea (Meynert, 1872; Forel, 1877). Willems ('11) used both terms, calling the cells internal to the mesencephalic root in the rabbit nucleus loci coerulei and those external to the root substantia ferruginea. By whatever name the cell mass is designated, there seems to be a considerable variance of opinion concerning the function and the types of cells constituting the nucleus of locus coeruleus.

In the material available for study, the nucleus of locus coeruleus appears as a rather well defined, compact group of cells (figs. 10,

11). It lies directly lateral to the dorsal tegmental nucleus, ventral to the nucleus of the mesencephalic root of V, medial to the root itself in its upper extent and medial to brachium conjunctivum in its lower extent. The nucleus begins rostrally at the level of the caudal end of nucleus medialis profundus in the isthmus and extends to the trigeminal levels of the pons. It is closely related with the nucleus of the mesencephalic root of V throughout its entire extent. It may be considered as representing a differentiated lateral pars of nucleus laterodorsalis tegmenti, with the main portion of which it is continuous rostrally. At certain levels the neurons of the nucleus of the mesencephalic root of V are intermingled with those of the nucleus of locus coeruleus (fig. 11). The neurons of the latter can be differentiated from those of the former, for they are much smaller, about half or one-third the size, and are not so deeply stained. These neurons of the nucleus of locus coeruleus are multipolar, medium-sized cells with various shapes: oval, triangular and elongated. They have relatively large nuclei with indistinct outlines. Coarse Nissl granules are irregularly distributed throughout their cytoplasm but rather concentrated near the periphery of the cell body. No pigment is found in these neurons. These observations seem to agree with those of Kuré (1899) and Weinberg ('28). Kuré described large and small cells in the nucleus of locus coeruleus of the rabbit. The large cells, he stated, were analogous to the cells in the nucleus of the mesencephalic root of V and underwent chromatolysis after cutting the trigeminal nerve, although the small cells were not affected. Weinberg also found two types of cells intermingled in the region, one of which was histologically different from those constituting the nucleus of the mesencephalic root of V. He considered this type as forming the nucleus of locus coeruleus.

Many workers such as Meynert (1872), von Kölliker (1896), Johnston ('09) and Allen ('19) regarded the cells in locus coeruleus as a part of the mesencephalic nucleus of the trigeminal nerve. Willems ('11) considered the gray of locus coeruleus as a separate nucleus. Ramón y Cajal ('09) and Weinberg ('28) believed that no contribution to the mesencephalic root of the trigeminal nerve comes from the nucleus of locus coeruleus. May and Horsley ('10) and Kosaka ('12) failed to find any chromatolysis in the cells of locus coeruleus, the former after sectioning the trigeminal nerve in the monkey and cat, the latter after cutting the mandibular division of the trigeminal nerve in the dog. These differences in opinion about the functional relations of these neurons is dependent largely upon differences in the establishment of the limits of the nucleus of locus coeruleus (Weinberg, '28; Sheinin, '30).

On the basis of their experimental study of the capillary bed of the nucleus of locus coeruleus in monkeys, Finley and Cobb ('40) concluded that this cell mass is distinct from the nucleus of the mesencephalic root of V. They showed difference in capillary richness in the two nuclei and in the character of the constituent cells.

Dorsal tegmental nucleus

In the isthmus region, a distinct group of neurons is identified on either side of the midline within the central gray. It occupies a position ventromedial to the laterodorsal tegmental nucleus and directly ventral to the medial longitudinal fasciculus. This nuclear group is known as the dorsal tegmental nucleus (fig. 10) or nucleus tegmenti dorsalis of von Gudden, who described it, together with the ventral tegmental nucleus, in 1889.

In general, the nuclear mass is circular in outline in cross section. In the middle third of its extent, it appears to consist of two distinct portions, a ventral and a dorsal part, with a few intervening scattered cells. The neurons of the two portions are almost the same except that those of pars dorsalis are slightly smaller and less numerous than those of pars ventralis. They are medium-sized, multipolar cells having various shapes from round or oval to triangular and fusiform. Frontally and caudally, the cells of the dorsal tegmental nucleus gradually fade into the surrounding periventricular gray without any sharp nuclear demarcation.

Nucleus of mesencephalic root of V

This nucleus has been studied by a number of authors after the first clear differentiation of the mesencephalic root of V from the trochlear nerve was given by Meynert (1872). Since the work of Johnston ('09), May and Horsley ('10), Willems ('11), Allen ('19) and Thelander ('24), it has been generally accepted that the mesencephalic nucleus of V contains primary sensory neurons, the processes of which course with the motor branches of the mandibular division of V, supplying the muscles of mastication and mediating muscle sensibility. Central collaterals from the mesencephalic root were traced to the motor nucleus of V by Ramón y Cajal (1896) and this observation has been confirmed by Wallenberg ('04 c), May and Horsley ('10) and others. Further evidence of the sensory character of the mesencephalic nucleus as based on cell type is offered in the work of Sheinin ('30), who carefully studied the cells in the dog and separated them on the basis of size and arrangement of chromophil substance into four types. However, Castaldi ('26), a more recent

exponent of the view that the mesencephalic nucleus of V is motor and not sensory, based his objections to current opinions on his study of the embryologic development of the nucleus. He stated that this nucleus develops precociously as does the motor nucleus of the trigeminal and is larger in the embryo, at a stage at which the muscles are relatively retarded in development, than it is in the adult. Castaldi also noted that the long processes of its neurons show the characteristics of neuraxes of neurons of the central nervous system, particularly since they do not have Nissl substance and are myelinated, and that to regard these processes as dendrites would imply that the dendrites developed here before neuraxes, which is contrary to the usual course of embryologic development.

The autonomic function ascribed to the nucleus of the mesencephalic root of V by Lewy, Droff and Grant ('38) has not been corroborated by Corbin and Harrison ('41 and '42) and Corbin ('40). These latter authors, in their experiments on the cat, demonstrated action potentials of the proprioceptive type when the masticator muscles of the cat were stretched. Although they were unable to find fibers of the mesencephalic root of V in the oculomotor or trochlear nerves, they were not prepared to regard the presence of such fibers as impossible.

In the material studied, the nucleus of the mesencephalic root of V (figs. 5 to 11) appears in cross section either as a short, interrupted, vertically curved band formed by a few cells with the concave surface of the band turning inward, or, sometimes, just as a few conspicuous neurons. It is found caudally at the level of the motor nucleus of the Vth nerve and extends rostrally to the level of the posterior commissure. The cells of the nucleus of the mesencephalic root of V are scattered along the outer border of the periventricular gray (for variations in different forms, see Weinberg, '28), ventral, lateral and dorsal to the aqueduct, but most of them are lateral to it (figs. 5 to 11). They are bordered on the outside by stratum album profundum. No cells are found in sections passing through the midline or close to it. Very few cells are found at the frontal end of the nucleus, through the level of the posterior commissure, or throughout the upper third of its extent, but they gradually increase caudalward. The nucleus also shifts ventralward from a rostral position lateral to the aqueduct into closer contact with the nucleus of locus coeruleus at its caudal end (fig. 10). It is dorsal, dorsolateral and lateral to the latter and a few of its cells are intermingled with those of the nucleus of locus coeruleus (fig. 11). The number of cells varies at different levels. On the whole, cells of the mesencephalic root of the trigeminal nerve lie farther ventralward in most mammals than in lower vertebrates, and in man extend to the motor nuclei of the oculomotor and

trochlear nerves, and are even intermingled with cells of these nuclei (Ariëns Kappers, Huber and Crosby, '36). Along its course, two major groups of neurons may be described, one at the level of the superior colliculus and the other in the isthmus. No definite group, but only scattered cells were seen in the material available at inferior collicular levels. Of the two groups, the caudal is the larger. The division of the nucleus of the mesencephalic root of V into lateral, medial and intermediate groups, such as is evident in many lower forms, is lacking in the mink. The augmentation of the caudal or isthmie portion of the nucleus has been noted for various mammals. It is evident in the cat and in rodents near the level of decussation of the trochlear nerve, in monkeys slightly in front of this level, and in man behind it (Weinberg, '28). In the guinea pig, Castaldi ('26) described an increase of cells at the level of the inferior colliculus, a decrease where the root passes downward and through the anterior medullary velum, and then an increase in planes through the motor nucleus of the trigeminal nerve. In the rodents studied by Weinberg ('28), the nucleus is not so well developed in the oculomotor region as in the cat, the monkey and man. Brown ('43) recognized three nuclear groups in dog and cat brains, the largest group being situated at superior collicular levels.

Cells of the mesencephalic root are rather uniform in outline. They are oval or pear-shaped. Two types of cells are identifiable — a large and a medium-sized neuron — although histologically they are almost alike. These neurons are mostly unipolar, but some of them are bipolar and a very few are multipolar. The two types of cells are scattered and intermingled with each other throughout the extent of the nucleus. They are not definitely located at any given level. In the mink, these neurons have definite outlines with distinct nucleoli. Fine and coarse Nissl granules are distributed throughout their cytoplasm. The large cells probably correspond to type A, and the smaller to types B and C of Sheinin ('30).

MIDTEGMENTAL NUCLEAR GROUPS

Nuclear groups associated with medial longitudinal fasciculus

Two cellular masses have been described in association with the medial longitudinal fasciculus. These are the interstitial nucleus of the fasciculus and the annular nucleus.

The cell group corresponding to the interstitial nucleus has been described under various names such as the interstitial nucleus of Ramón y Cajal ('11), nucleus commissurae posterioris of von Kölliker (1896), upper oculomotor nucleus of Darkschewitsch (1889) and nucleus of Darkschewitsch of Zeri (1895). The last name is often con-

fused with the nucleus of Darkschewitsch as designated by Ramón y Cajal which is described in this paper under the name used by this author and by Ingram and Ranson ('35).

The interstitial nucleus of the medial longitudinal fasciculus is present, at the level of the rostral pole of the oculomotor nucleus, as a small circular cell group ventrolateral to the ventral nucleus of the posterior commissure, dorsolateral to the oculomotor nuclear complex and directly dorsal and dorsolateral to the medial longitudinal fasciculus (figs. 2, 3). In its course caudorostrally, it becomes more and more distinct, but rather abruptly disappears frontally at the level of the rostral tip of the nucleus medianus anterior (or rostral Edinger-Westphal nucleus). The cells of the interstitial nucleus of the medial longitudinal fasciculus are not closely packed together. They are relatively large and multipolar with oval and polygonal shapes. They have large nuclei with distinct nucleoli and coarse Nissl granules. This nucleus is a derivative, in part at least, of nucleus reticularis superior mesencephali of lower forms.

Another nuclear group associated with the medial longitudinal fasciculus is the annular nucleus. It lies on either side of the midline, ventral to the medial longitudinal fasciculus and the nucleus of the oculomotor nerve, and dorsal to the decussation of the brachium conjunctivum or superior cerebellar peduncle (figs. 7, 8). It begins caudally at the level of the frontal half of the trochlear gray and ends rostrally at a plane through the caudal tip of the red nucleus. It has a half-ring shape with an irregular and indistinct outline. The concave surface turns dorsalward embracing the medial longitudinal fasciculus.

The nucleus appears to occupy a position comparable in part to that of cells described by Castaldi ('23) as *nucleo anulare del fascio longitudinale mediale* and also to the subfascicular nucleus of the oculomotor complex of Frank ('21). The nuclear mass is composed of irregularly scattered, small to medium-sized multipolar neurons with elongated and fusiform shapes. Their nuclei and Nissl granules are indistinct. Toward the midline, the neurons of the nucleus blend with the cells of the raphé.

Red nucleus

The red nucleus appears as a conspicuous oval group of cells in the tegmental region of the midbrain. It extends from a plane through the caudal end of the superior colliculus to the subthalamic region, disappearing at levels through the caudal end of the mammillary body and the posterior commissure by blending indistinctly with the reticular formation. The red nucleus occupies a position ventrolateral

to the oculomotor nuclei, the medial longitudinal fasciculus and the dorsal tegmental decussation. Substantia nigra is ventrolateral to it.

The fibrous capsule of the carnivore red nucleus is formed by the decussated fibers of the superior cerebellar peduncle, according to von Monakow ('10) and Rioch ('29 b). In the toluidin blue preparations this relation is not clear. The absence of such a capsule in the dog was noted by Hatschek ('07).

The red nucleus has been subdivided in many ways and it is uncertain to what extent the subdivisions are directly comparable in the different mammals (Foix and Nicolesco, '25, quoted from Ariëns Kappers, Huber and Crosby, '36). However, in the material studied, three subdivisions of the nucleus have been observed, each of which will be described separately.

The magnocellular red nucleus (figs. 2 to 5) has the greatest length of any of the three parts and is present throughout the entire extent of the complex. It is most conspicuously seen at the caudal pole and gradually diminishes in size as it is traced rostrally. At the caudal end of the nucleus, it is ventrolateral to the parvocellular portion but, as it is followed rostrally, it shifts medialward so that it becomes first ventral (fig. 5) and then ventromedial to the parvocellular part (fig. 2). Its cells are large, multipolar and pyramidal neurons of the type recognized as efferent in character.

In the material studied, the parvocellular portion occurs for about the middle two-fifths of the entire extent of the red nucleus. A less frontal extent has also been found in the rabbit (Davenport and Ranson, '30). Its cells are small, multipolar and triangular or spindle-shaped and are less closely packed than in the magnocellular portion.

The medial part of the red nucleus, at about the middle of its extent or at the level of emergence of root fibers of the oculomotor nerve, is penetrated through both magnocellular and parvocellular portions by the fibers of that nerve, separating a few scattered cells from the main nucleus. This secondary subdivision has formed adventitious groups (Davenport and Ranson, '30). In the material available, only a few scattered cells of this type have been observed (fig. 5).

A small, round mass of tiny cells, corresponding to the group which von Monakow ('10) called nucleus minimus, is found lateral to the magnocellular portion at the level of the midregion of the red nucleus (figs. 3 to 5). Its neurons are smaller than those of the parvocellular portion. They are multipolar, polygonal and, in some instances, triangular in shape, with large nuclei and prominent nucleoli. They have distinct Nissl granules. The cell group was also described by Davenport and Ranson ('30). Many others (Forel, 1877, in the dog; Hatschek, '07, in carnivores and primates; Ramón

y Cajal, '09-'11, in the cat; and also Rioch, '29 b, in the cat) have described the red nucleus in carnivores without mentioning nucleus minimus.

Deep mesencephalic gray (nucleus mesencephalicus profundus)

Nucleus profundus mesencephali, the deep mesencephalic or tegmental gray, consists of multipolar, medium-sized, triangular-shaped and small-sized fusiform neurons scattered in the area ventral to the central gray, dorsal to substantia nigra and lateral to the midline (fig. 5). This mesencephalic gray is found throughout the midbrain region, extending from the upper pons level caudally to the caudal end of the diencephalon frontally. On account of its general reticular character, Castaldi ('23) regarded it as the direct continuation forward of nucleus reticularis of the pons. Deep mesencephalic gray is seen best at the levels of the red nucleus; there two well organized groups of reticular cells are observed. One of these is located dorsal to the red nucleus, pars dorsalis of nucleus mesencephalicus profundus, and the other is lateral to the same nucleus, pars lateralis of nucleus mesencephalicus profundus. The dorsal group is more distinct than the lateral group and its neurons are larger than those of the latter. Cells of both dorsal and lateral groups are not closely arranged. Deep mesencephalic gray or nucleus mesencephalic profundus has received a number of names (see Castaldi's paper, '23, p. 144). One of the most common names is that of nucleus lateralis mesencephali of Marburg ('03).

Ventral tegmental area and nucleus of mammillary peduncle

Small clusters of cells appear in the ventral part of the mesencephalon lateral to the interpeduncular nucleus throughout the entire extent of the midbrain (figs. 3 to 5). This is the ventral tegmental area of Tsai ('25). Caudally, it seems to continue from the rostral tip of the scattered pontine gray without specific boundary. Frontally, this ventral tegmental gray blends with the gray of the hypothalamus.

In this ventral tegmental gray, a small, rather oval group of more closely arranged cells may be observed. This small group of cells has been designated the nucleus of the mammillary peduncle (figs. 4 and 5; see also Papez, '23, '32, and Fox, '41). It occupies a position lateral and dorsolateral to the interpeduncular nucleus, ventrolateral to the interstitial nucleus of the commissure of Forel, directly medial to the nucleus of the basal optic root and ventromedial to the red nucleus. It lies in relation with fibers of the mammillary peduncle.

The ventral tegmental gray corresponds to nucleus ventralis tegmenti of Tsai ('25, fig. 4), and Rioch ('29 b, fig. 2). It is not the same as nucleus ventralis tegmenti of von Gudden and Ramón y Cajal ('09-'11). The latter nucleus is described in this paper under the name of nucleus medialis profundus.

At the level of emergence of the oculomotor fibers, the ventral tegmental area and its differentiated portion, the nucleus of the mammillary peduncle, are traversed by some of the most medial fibers of that nerve (figs. 4, 5). The ventral tegmental gray has very indefinite boundaries and in some sections it is difficult to differentiate it from the medial part of substantia nigra. Kosaka and Hiraiwa ('15) and Castaldi ('23) considered it as a part of substantia nigra. In the material available for study, the neurons of both the ventral tegmental area and the nucleus of the mammillary peduncle are much the same. They vary in size from small to large neurons and in shape from oval, fusiform or polygonal to triangular. Most of the large cells are triangular and much like the constituent elements of substantia nigra. They have large nuclei, coarse Nissl granules and prominent nucleoli. These large neurons are intermingled with small and medium-sized cells.

Nucleus medialis profundus

A group of neurons in the tegmentum of the isthmus, behind the mesencephalon, situated on either side of the raphé, ventrolateral to the medial longitudinal fasciculus and the dorsal tegmental nucleus and at the level of decussation of the trochlear fibers is termed nucleus medialis profundus (Castaldi, '23). The gray mass has a number of other names (see list in Castaldi, '23), one of the most common of which is nucleus ventralis tegmenti of von Gudden (1889) and Ramón y Cajal ('09-'11). The cell group is circular in outline, with indistinct boundaries (fig. 9). Caudally and frontally, it disappears by fading indistinctly into the surrounding gray. This nucleus is most conspicuous throughout the middle of its extent, the rostral tip being slightly more ventral than the rest of the nucleus.

The neurons constituting nucleus medialis profundus are deeply stained in the toluidin blue preparations and thus the cell mass stands out distinctly from the surrounding gray. The cells are medium-sized and multipolar and have irregularly oval to triangular or spindle shapes. Their nuclei are fairly large with indistinct outlines. Nissl granules were not clearly observed. Comparative studies show that this nucleus is better developed in lower than in higher mammals (Hatschek, '03). A fibrous capsule such as that described by Hatschek is not identifiable in the material studied.

Marginal nucleus of superior cerebellar peduncle

At the level of the inferior collicular nucleus, clusters of small multipolar cells are seen scattered among the fascicles and on both sides of the superior cerebellar peduncle, as its courses rostromedio-ventrally toward its decussation. This group of cells is the so-called marginal nucleus of the peduncle (fig. 10), and is present throughout the inferior collicular level. It approaches pars lateralis of nucleus mesencephalicus profundus.

Cuneiform area

The cuneiform area (figs. 9, 10) lies between the periventricular gray on its dorsomedial side and the inferior colliculus on its dorso-lateral side, and occurs throughout the extent of the inferior collicular nucleus. This area consists of two types of scattered cells: small, fusiform or oval, multipolar neurons which tend to be surrounded by medium-sized, multipolar, triangular-shaped cells. Some fibers from the optic tectum and also some of the lemniscal system pass through this area, though they are not clearly seen in the available material.

Certain pretectal and subtectal components of tegmentum

Pretectal nucleus. In the cross sections of the rostral portions of the mesencephalon, at the level of the posterior commissure, medial to the large-celled nucleus of the optic tract, dorsal to the dorsal nucleus of the posterior commissure and slightly dorsolateral to pars dorsalis of the periventricular gray and the posterior commissure lies a group of neurons which is designated as nucleüs pretectalis (fig. 2). This gray corresponds to the pretectal nucleus of Tsai in the opossum ('25) and of Ingram, Hannett and Ranson in the cat ('32) and, in general, to the pretectal area of Gurdjian in the rat ('27).

The pretectal nucleus of the present account appears in the available transverse series as a small group of neurons rather circular in outline but with very indistinct boundaries (fig. 2). Frontally, it is continuous with the caudal portion of the diencephalon and caudally it disappears at the level of the posterior commissure by fading into the surrounding tectal gray (stratum griseum intermediale) without sharp demarcation. The neurons of this nuclear mass are small, multipolar and lightly stained. Most of them are triangular in outline, but some are fusiform and irregular in shape with very fine Nissl granules.

Nuclear gray associated with lateral lemniscus. Along the course of the lateral lemniscus, three nuclear groups — an upper or dorsal,

a caudal ventral, and a rostral ventral nucleus of the lateral lemniscus — may be recognized.

The upper or dorsal nucleus of the lateral lemniscus appears in the cross section series as a rather elongated group of neurons dorsally located among the fibers of the lateral lemniscus. It is ventral to the inferior colliculus, lateral to nucleus medialis profundus and dorsal to the caudal ventral nucleus of the lateral lemniscus (figs. 9, 10). It extends from the level of the caudal end of the nucleus medialis profundus to about that of the rostral tip of the same nucleus. In many mammals, according to Ariëns Kappers, Huber and Crosby ('36) and others, this nucleus, which is situated in front of the level of entrance of the trigeminal nerve in the lateral part of the field close to the lateral lemniscus, from its position, as well as from the general character of its cells, its fiber connections and relations with the inferior colliculus, suggests part at least of the nucleus isthmi of reptiles. The dorsal nucleus of the lateral lemniscus corresponds to the parabigeminal body of Papez ('29). This nucleus, as it is traced rostrocaudally, gradually becomes smaller toward the caudal end. Its neurons are closely packed, medium-sized, multipolar cells and are triangular or fusiform in outline. Their nuclei are relatively large. Fine Nissl granules are distributed throughout their cytoplasm. In the cross sections studied, the neurons of this nucleus are grouped peculiarly, in linear arrangement although the cellular lines are somewhat irregular (fig. 9).

At about the same level or slightly caudalward to the dorsal nucleus of this fiber system, and also along the course of the lateral lemniscus, is a group of cells ventrally placed which is described as the caudal ventral or lower nucleus of the lateral lemniscus (figs. 9, 10). It is connected with the dorsal nucleus by clusters of scattered cells. The caudal ventral nucleus is rather oval or elongated in shape with irregular, indistinct boundaries. It becomes larger and more conspicuous toward its caudal end. It extends farther caudalward than does the dorsal nucleus. Its cells are smaller than those of the latter cell mass, and are also small multipolar neurons, oval and triangular in shape with relatively large nuclei and very fine Nissl granules. This caudal ventral nucleus, especially in its dorsal portion, presents a linear arrangement of its constituent cells similar to that seen in the dorsal nucleus of the lateral lemniscus.

The rostral ventral nucleus of the lateral lemniscus, the smallest nucleus of the three cell masses associated with the lateral lemniscus, is the most rostral and has the shortest extent (fig. 8). It appears caudally at the level of the caudal tip of the trochlear nucleus and extends rostrally, toward the medial geniculate body, to the level

of the frontal end of the same nucleus. It lies also along the course of the lateral lemniscus. The rostral ventral nucleus is in line with the dorsal nucleus of the lateral lemniscus, but nearer to the lateral surface of the midbrain. This group of cells is fusiform in outline, and is best developed through the middle of its extent. The neurons constituting it are mostly small multipolar cells, triangular in outline. A few of them are medium-sized multipolar cells. They are lightly stained in the available Nissl material and have relatively large nuclei and coarse Nissl granules.

MIDLINE NUCLEAR GROUPS

Linear nuclear gray

The linear nuclear gray is an unpaired cell mass which appears in cross section as an elongated column ventral to the central gray. It extends throughout the midbrain from the pontine raphé caudally to the caudal end of the diencephalon frontally. Three subdivisions can be recognized—the caudal, the intermediate and the rostral linear nuclei.

The caudal linear nucleus is located at the midline between the medial longitudinal fasciculi and the nuclei mediales profundi of the two sides (figs. 9, 10). It extends forward from the gray of the pontine raphé to the decussation of the superior cerebellar peduncle. A few scattered cells of the same type form an interstitial nucleus for that decussation. There is a cellular connection between the dorsal part of the linear nuclear gray and the ventral part of pars centralis of the dorsal nucleus of the raphé, so that pars centralis and the caudal linear nuclear gray appear, in the cross section, as a single elongated cell column extending from the cerebral aqueduct dorsally to the pontine raphé ventrally (fig. 9). This column is distinct from the surrounding gray because of its deeply stained neurons. The caudal linear nuclear gray is composed of intensely stained, irregularly scattered neurons. They are small to medium-sized, spindle- and fusiform-shaped neurons with indistinct nuclei and Nissl granules.

The intermediate portion of the linear nucleus is not so distinct as the caudal part, consisting of cells which are few in number and not closely arranged. It extends from the rostral pole of the decussation of the superior cerebellar peduncle caudally to the commissure of Forel frontally, lying between the red nuclei of the two sides. At the level of the interpeduncular nucleus, there is a small group of rather large, multipolar, deeply stained neurons between the ventral part of the intermediate linear nuclear gray and the dorsal part of the interpeduncular nucleus, similar to those of the caudal linear gray except that they are less intensely stained.

The rostral linear nucleus is continuous with the intermediate linear gray. It extends from a level in front of the commissure of Forel to the caudal pole of the diencephalon, in the same relation to the red nucleus as is the intermediate linear gray. The cells are few in number, widely scattered and of the same type as those of the intermediate linear gray.

Interstitial nucleus of commissure of Forel

The interstitial nucleus of the commissure of Forel (figs. 2 to 4) appears as an unpaired midline group of scattered neurons intercalated among the commissural fibers. Caudally, it seems to be directly continuous with the dorsal part of the rostral portion of the interpeduncular nucleus. Rostrally, the interstitial nucleus appears to blend with the mammillary nucleus and the surrounding hypothalamic gray without definite line of demarcation. It is most obvious in the middle half of its extent. The group of cells is rather oval in outline with indistinct and irregular boundaries. It lies between the ventral tegmental area and the nucleus of the mammillary peduncle of one side and corresponding areas on the other side (figs. 2 to 4). In its lower portion, oculomotor root fibers form its lateral boundaries. Some of the most medial of these fibers traverse the nucleus in certain sections (fig. 4). As the interstitial nucleus of the commissure of Forel is traced caudorostrally, at about the middle third of its extent, the dorsal part of the nucleus appears to spread out laterally into two wings (fig. 3). The dorsal part of each wing extends toward the magnocellular part of the red nucleus and blends with the latter. The ventral part spreads toward the ventral tegmental gray, the nucleus of the mammillary peduncle and the medial part of substantia nigra. The interstitial nucleus of the commissure of Forel corresponds to the interstitial nucleus of the supramammillary decussation figured by Rioch ('29 a, figs. 9 to 11).

The interstitial nucleus is constituted of various sized neurons. At least two types can be identified in the material studied. One of these is a large, multipolar cell with an oval, elongated or triangular cell body. It has a cell nucleus and a large, distinct nucleolus and the processes are unusually prominent in the available material. The coarse and distinct Nissl granules are distributed throughout the cell cytoplasm. Neurons of this type are not very numerous and are seen more usually in the two wings of the nucleus. A second, more widely distributed type, has an oval or round cell body, much smaller than that of the first type and less clearly delimitable. The outlines of the cell nucleus and nucleolus are difficult to trace, and the Nissl granules are very fine indistinct and less in number than in the other type of

neuron. The processes are short, less numerous and less easily followed than those of the first type. These smaller cells are distinguished throughout the nucleus, intermingled with the larger neurons.

Interpeduncular nucleus

The interpeduncular nucleus is a conspicuous element of the mid-ventral region of the mesencephalon and is easily recognizable. It is located between the two cerebral peduncles in the field overlying the interpeduncular fossa (figs. 3 to 6). It is found continuously from the upper pontine gray caudally to the caudal end of the mammillary body rostrally, fading out into the ventral tegmental gray without a definite line of demarcation. At the level of emergence of the fibers of the oculomotor nerve, the interpeduncular nucleus is penetrated by some of those fibers (fig. 5). This gray mass is an unpaired structure throughout its entire course.

Two types of cells are found in the interpeduncular nucleus. One is a medium-sized, fusiform or triangular multipolar neuron with a large nucleus. Its Nissl granules are not very distinct. The cells of this type are intermingled with small, round or oval more deeply stained neurons, having tiny but distinct cell nuclei. In the superficial part of the nucleus, the larger cells are more numerous than the smaller type, but in the central portion they are surpassed in number by the smaller neurons. Cells at the center of the interpeduncular nucleus are more closely arranged than those of the superficial zone. There is no definite line of demarcation between the two zones such as was described in the rabbit by Ramón y Cajal ('09-'11). Early, Forel (1877) recognized the presence of these small and large cells in the interpeduncular nucleus in the rabbit.

BASAL MIDBRAIN GRAY

Substantia nigra

In transverse sections, substantia nigra appears as two irregular, thick cell bands overriding and in part intermingled with the fiber bundles of the cerebral peduncle (figs. 2 to 8). It begins caudalward at the level of the upper border of the pons, replacing pontine gray, and continues uninterruptedly through the length of the midbrain into the subthalamic region of the diencephalon, where it gradually disappears. Its forward projection into the ventral part of the carnivore diencephalon was also described in the cat by Winkler and Potter ('14).

Substantia nigra is not equally thick throughout. Caudally, towards the lateral sulcus, it becomes thin, although it has considerable thick-

ness near the medial side of the cerebral peduncle. Farther forward these relations are reversed, the lateral part being the better developed portion. The medial part of substantia nigra is traversed by the emerging rootlets of the oculomotor nerve (fig. 5). The surface turned towards the tegmentum is slightly concave in the caudal part, straight in the middle portion and slightly convex rostralward. In the material available for study, substantia nigra may be divided into the three parts which Rioch ('29 a) and others have described in carnivores.

Zona compacta is the most conspicuous of any of the three portions of substantia nigra and is found throughout the entire extent of the nuclear mass (figs. 2 to 8). Its cells are closely arranged, and are small or medium-sized and mostly polygonal or fusiform in shape. They have large nuclei and distinct Nissl granules. This portion of substantia nigra overrides the cerebral peduncle throughout its extent.

Zona reticulata, which is merely a prolongation of cells of zona compacta, appears as scattered neurons intercalated among the fibers of the cerebral peduncle (figs. 3 to 5). There is no definite fibrous layer between this zone and zona compacta. This portion of substantia nigra extends from a plane passing through the rostral end of the decussation of the superior cerebellar peduncle to a level through the caudal end of the mammillary body. Its cells are much the same as those of zona compacta. Ramón y Cajal ('09-'11) described this part as an inferior zone of substantia nigra.

Pars lateralis is found dorsolateral to zone compacta and ventromedial to the medial geniculate body (fig. 5). It has about the same extent as does zona reticulata. The neurons constituting this part of substantia nigra are fusiform and slightly smaller than those of zone compacta. Histologically, they are much like those of the other two portions of the nuclear complex.

Nucleus of basal optic root

The nucleus of the basal optic root with its connections in various mammals has been studied recently in detail by Gillilan ('41). In the mink, it is an oval cell mass with indistinct and irregular boundaries, which occupies a position along the inner border of substantia nigra (figs. 3 to 5). It has so close a relationship to this latter gray that, in some sections, it is rather difficult to differentiate clearly between them. The constituent elements are also similar to those of substantia nigra in the shrew, the bat, and the cat, and probably generally in mammals.

In the mink, the nucleus of the basal optic root begins caudally at the level of the caudal pole of the interpeduncular nucleus or the caudal part of the red nucleus. It disappears frontally at the caudal

end of the mammillary body. In the middle third of its extent, the nucleus appears, in cross sections, to consist of two portions—a lateral or dorsolateral and a medial or ventromedial subdivision—indistinctly separated from each other (fig. 3). Wallenberg ('04) also found two portions of this nucleus in the guinea pig. He termed the dorsolateral group of cells "ganglion ectomammillare dorsalis" and the ventral group "ganglion ectomammillare ventralis." A small band of cells connects the two nuclear masses. The form and position of the ventral nuclear mass are, as Wallenberg stated, similar to those of the avian ganglion ectomammillare (Huber and Crosby, '29). This was the embryonic position of nucleus tractus optici basalis and as the main group of cells was shifted to its dorsolateral position with the downgrowth of the peduncular fibers, a small number of the cells retained the original relationship. Kosaka and Hiraiwa ('15) described this separation of the nuclear elements in the dog also.

In its upper portion, the nucleus of the basal optic root is traversed by oculomotor nerve fibers (fig. 5). The neurons of this nuclear mass are mostly small and medium-sized, are multipolar but with various shapes—irregular, elongated and triangular. They have relatively large nuclei but rather indistinct cell outlines. The nucleoli are not very distinct. The cells are smaller than those of substantia nigra.

SUMMARY

Among the periventricular group, the eye-muscle nuclei probably present the most interesting relations. A forerunner of the central nucleus of Perlia or paramedian nucleus occurs in midregions of the chief oculomotor gray. Caudal and rostral to this level, the chief oculomotor gray is distinctly bilateral. No central caudal nucleus was identified. The Edinger-Westphal nuclei of the two sides are fused rostrally, but separate caudally. Trochlear nuclei are distinctly separated from the oculomotor gray. No posterior trochlear nucleus has been identified on either side of the brain.

Two portions were recognized in the dorsal tegmental nucleus—the dorsal and ventral parts. In this respect, the nucleus differs from that of any other mammals considered in the present series of papers.

A nucleus of locus coeruleus, probably differentiated from the lateral part of the laterodorsal tegmental nucleus of lower forms, has been recognized in the mink. It is clearly definable

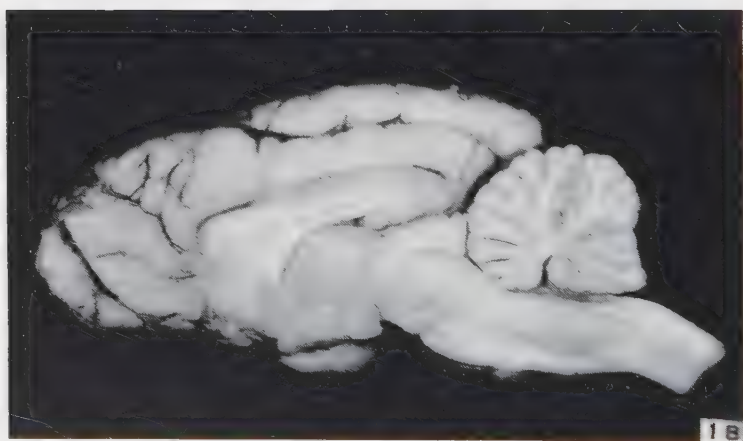
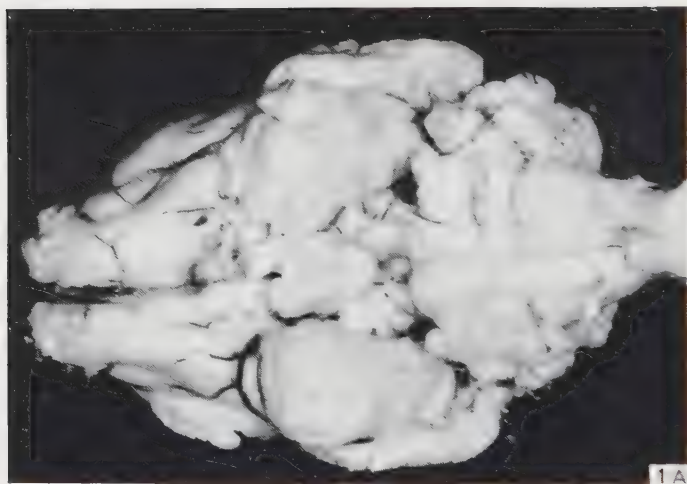
from the nucleus of the mesencephalic root of V on the basis of cell differences, although the neurons of the two nuclear masses are somewhat intermingled. Only two major cell groups of the nucleus of the mesencephalic root of V, one at superior collicular levels and the other in the isthmus, have been identified in the mink.

Among the midtegmental nuclear groups, the red nucleus is probably the most interesting. In addition to a parvocellular and a large magnocellular portion, a nucleus minimus, such as that described by von Monakow (1895), has been recognized. The fibrous capsule, described by von Monakow ('10) and Rioch ('29 b) as characteristic of carnivore red nucleus, is not clearly differentiable in the mink series studied for this paper.

Of the linear complex, the caudal linear group is the best developed in the mink. The interstitial nucleus of the commissure of Forel, consisting of scattered neurons among the fascicles of this system, has the characteristic relations to the red nucleus, substantia nigra, the nucleus of the basal optic root and the mammillary body, as it spreads laterally from the midline along the course of its associated fibers. The interpeduncular nucleus is a conspicuous gray mass in the ventral midline region of this carnivore, being found throughout the extent of this brain block.

Substantia nigra has the three portions and the relations described for carnivores by Rioch ('29 b) and others. The nucleus of the basal optic root lies in intimate relations with it, resembling it closely in general appearance.

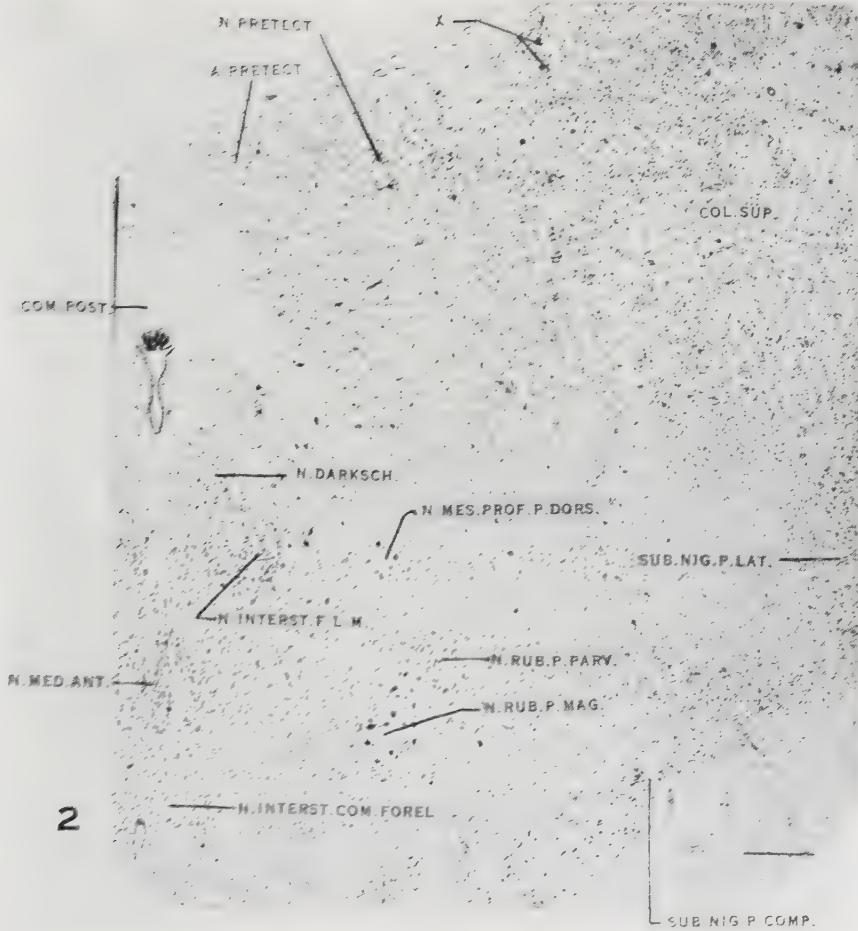
PLATE 1



1a Photograph of the ventral aspect of the mink brain. $\times 2$.

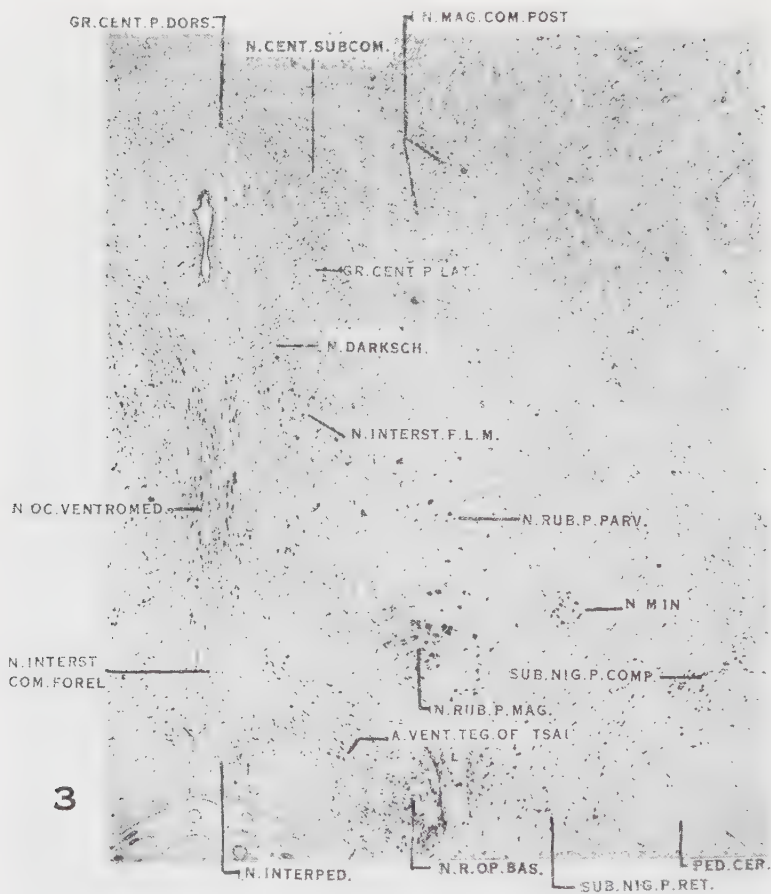
1b Photograph of the mink brain as seen in midsagittal section. $\times 2$.

PLATE 2



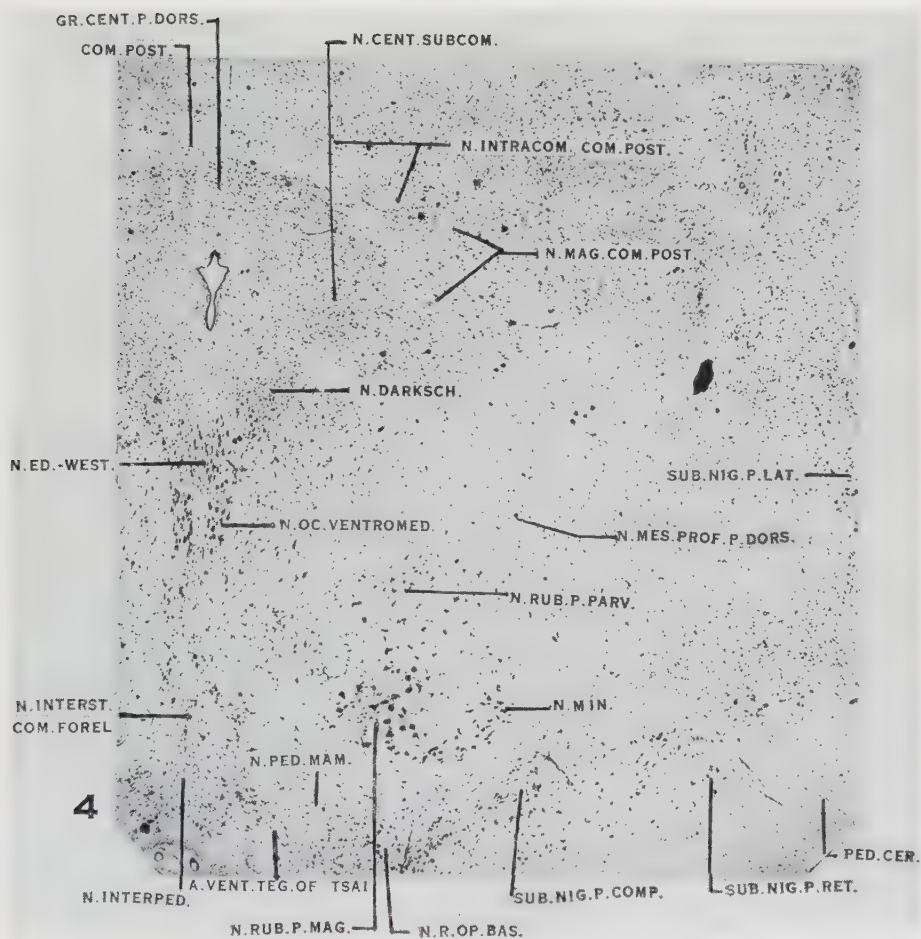
2 Photomicrograph of a transverse section of the midbrain of the mink in a plane through the posterior commissure and the nucleus medianus anterior. At this level both parvocellular and magnocellular portions of the red nucleus are present. Toluidin blue preparation. $\times 20$.

PLATE 3



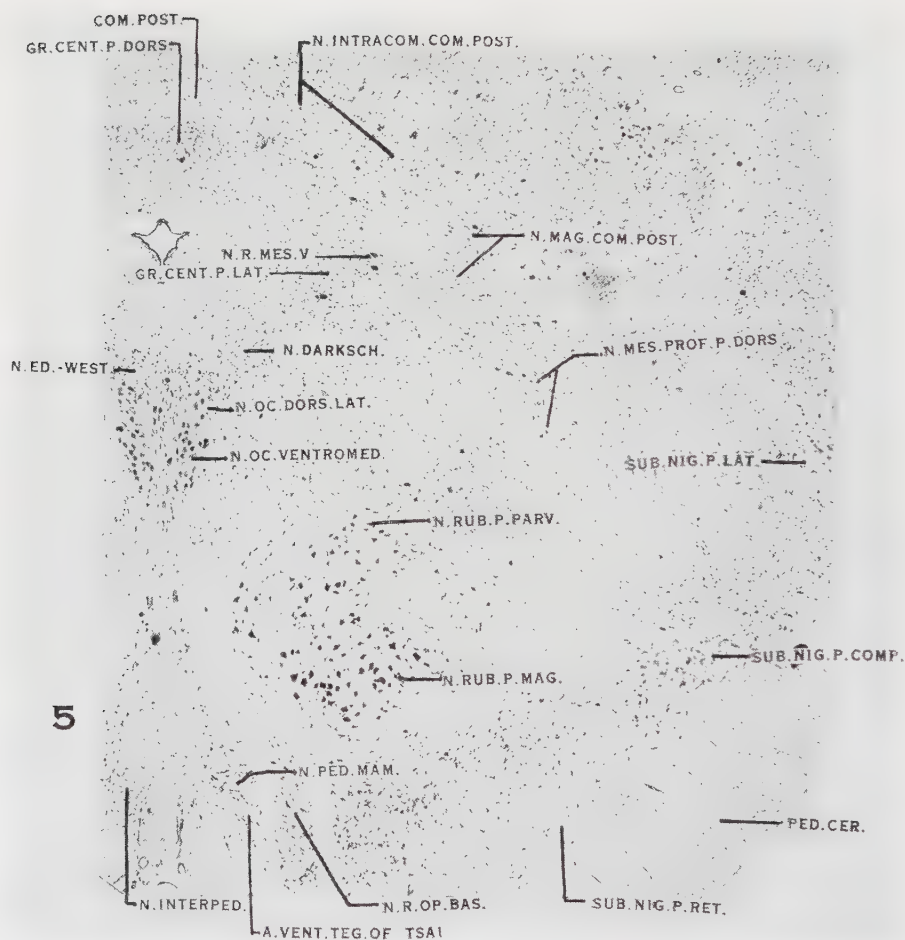
3 Photomicrograph of a transverse section of the midbrain of the mink immediately caudal to the plane of figure 2. Toluidin blue preparation. $\times 20$.

PLATE 4



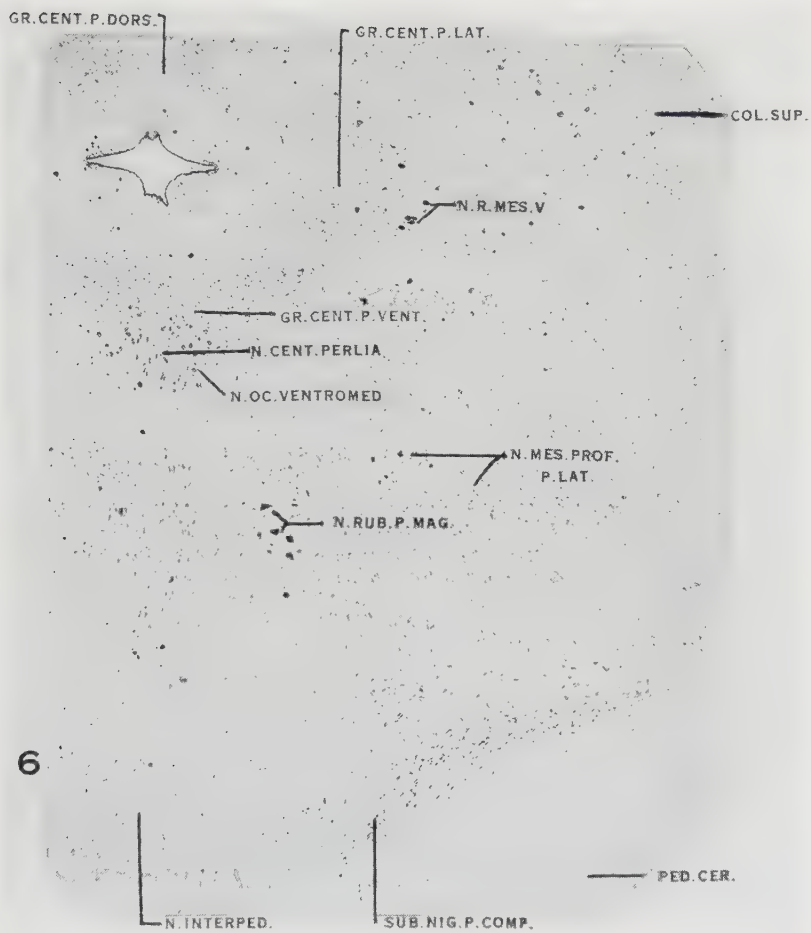
4 Photomicrograph of a section of the same series as figure 3 at a slightly more caudal level. Toluidin blue preparation. $\times 20$.

PLATE 5



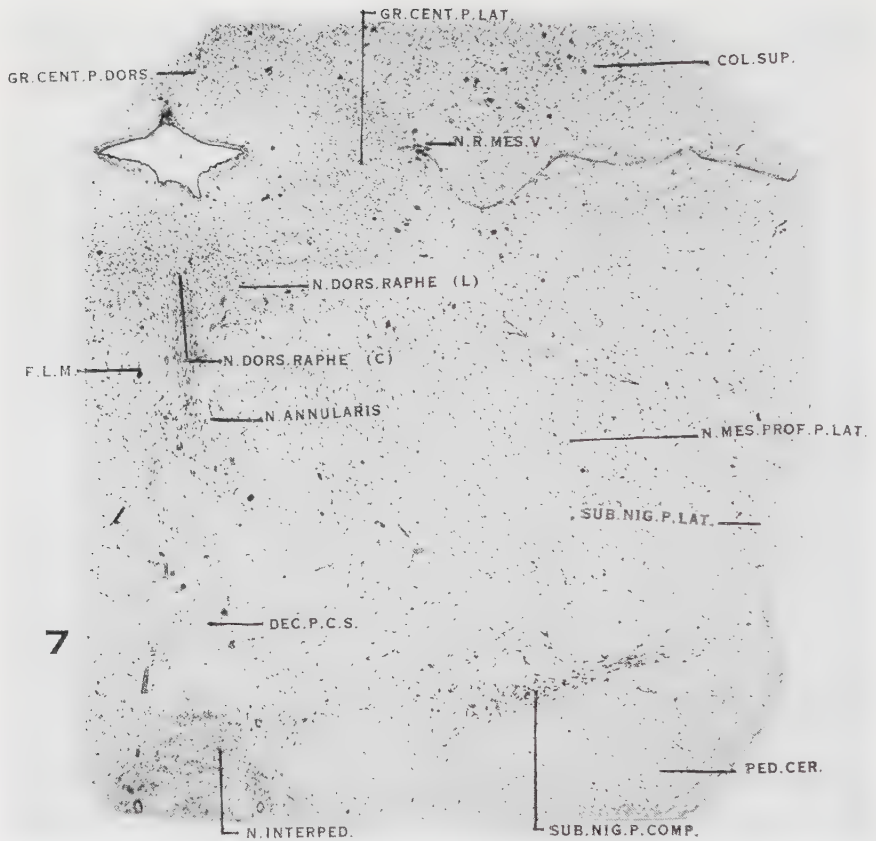
5 Photomicrograph of a section of the mink brain at the level of greatest development of the oculomotor complex. Toluidin blue preparation. $\times 20$.

PLATE 6



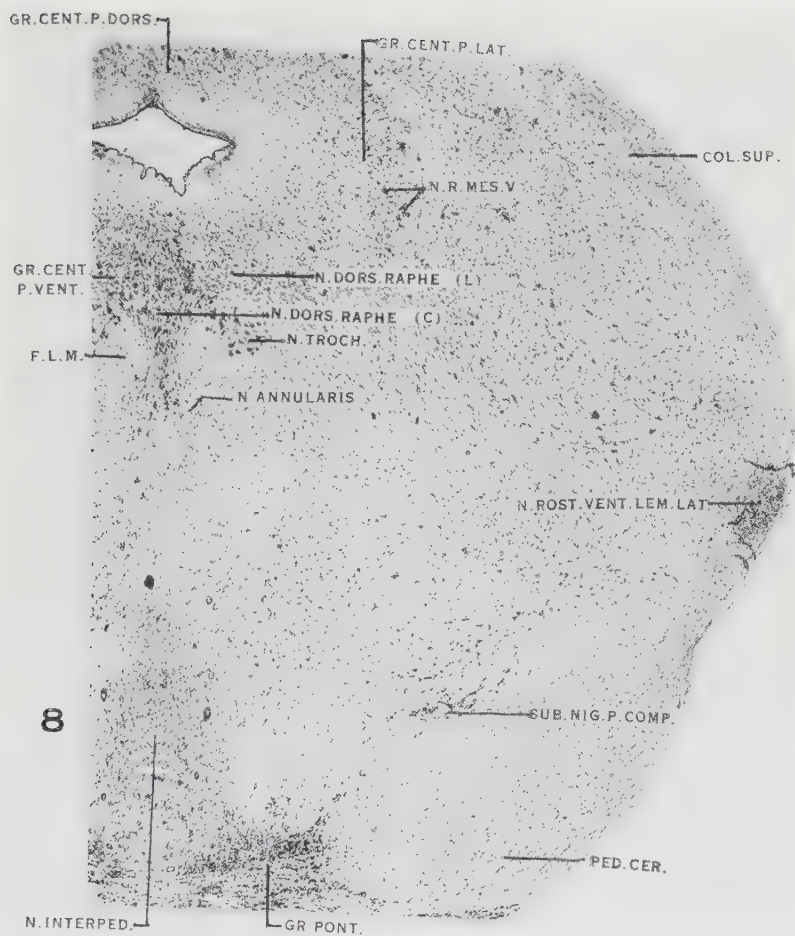
6 Photomicrograph of a section through the midbrain of the mink at the level of the central nucleus of Perlia. Toluidin blue preparation. $\times 20$.

PLATE 7



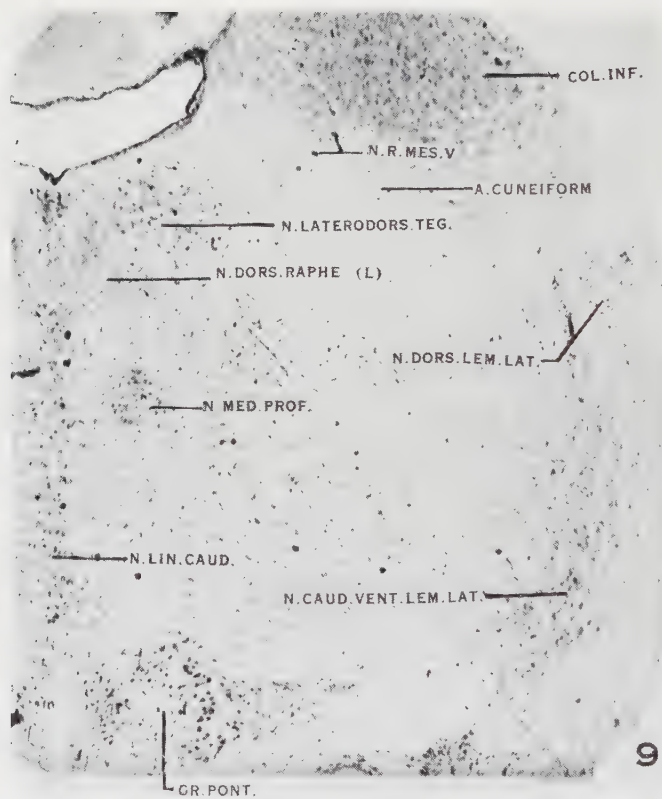
7 Photomicrograph of a section caudal to that of figure 6 showing the annular nucleus of the medial longitudinal fasciculus and the dorsal nucleus of the raphe. Toluidin blue preparation. $\times 20$.

PLATE 8



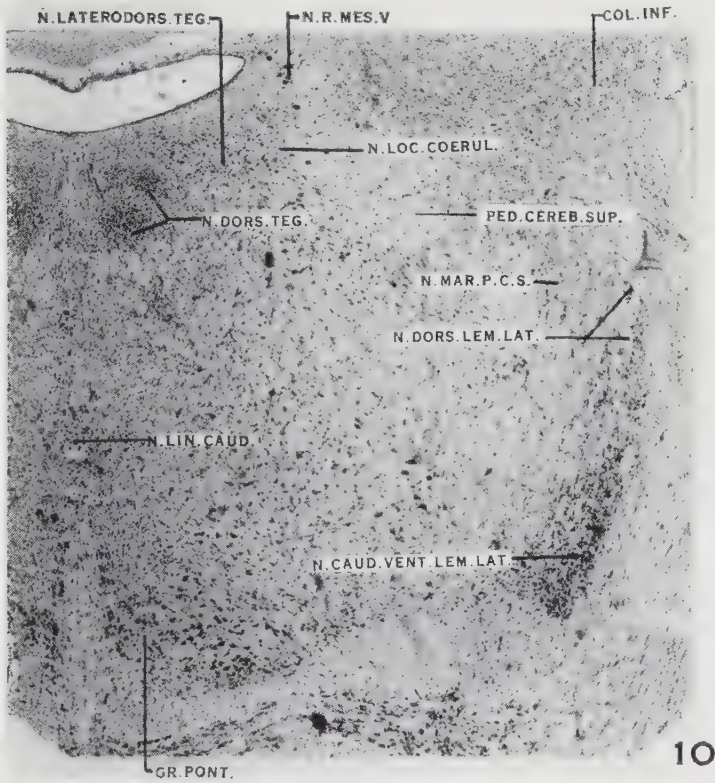
8 Photomicrograph of the mink brain at a level showing the dorsal nucleus of the raphe and the trochlear nucleus. Toluidin blue preparation. $\times 20$.

PLATE 9



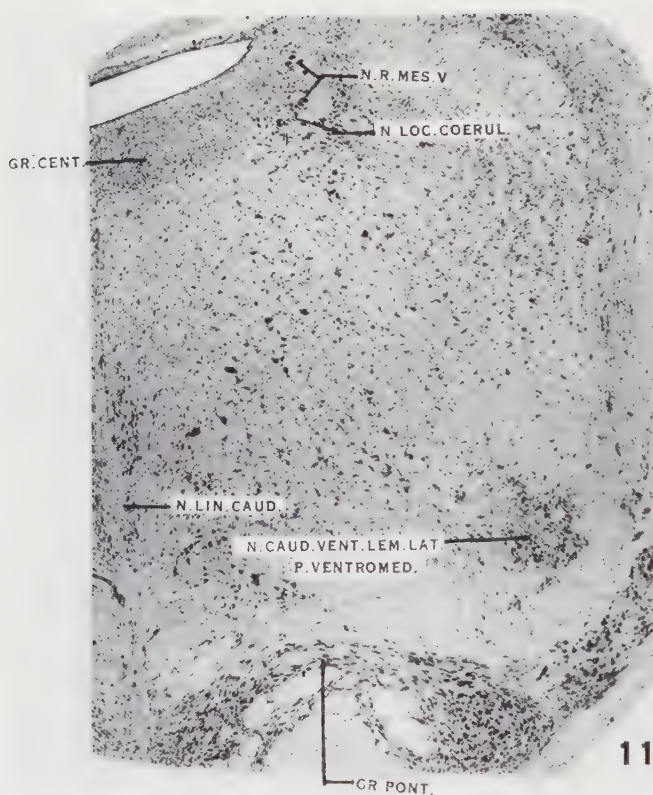
9 Photomicrograph of a transverse section of the mink brain through the laterodorsal tegmental nucleus. Toluidin blue preparation. $\times 20$.

PLATE 10



10 Photomicrograph of a section through the caudal pole of the midbrain of the mink showing the dorsal tegmental and the laterodorsal tegmental nuclei. Toluidin blue preparation. $\times 20$.

PLATE 11



11 Photomicrograph of a section of the mink brain through the isthmus region caudal to the dorsal tegmental nucleus. It shows the intermingling of the cells of locus coeruleus and those of the nucleus of the mesencephalic root of V. Toluidin blue preparation. $\times 20$.

LITERATURE CITED

- ADLER, A. 1942 Melanin pigment in the brain of the gorilla. *J. Comp. Neur.*, vol. 76, pp. 501-507.
- ALLEN, W. F. 1919 Application of the Marchi method to the study of the radix mesencephalica trigemini in the guinea pig. *J. Comp. Neur.*, vol. 30, pp. 169-216.
- ANDO, SYUZIRO 1937 Zur Zytoarchitektonik des Thalamia beim Kaninchen. *Folia Anat. Japonica*, vol. 15, pp. 361-410.
- ARIËNS KAPPERS, C. U. 1921 Vergleichende Anatomie des Nervensystems. E. F. Bohn, Haarlem, 2 vols.
- ARIËNS KAPPERS, C. U., G. C. HUBER AND E. C. CROSBY 1936 The comparative anatomy of the nervous system of vertebrates, including man. The Macmillan Co., New York, 2 vols.
- BACH, L. 1898 Zur Lehre von den Augenmuskellähmungen und den Störungen der Pupillenbewegung. *Archiv f. Ophthal.*, Bd. 48, S. 339-386.
- BAILEY, F., O. S. STRONG AND A. ELWYN 1925 Textbook of histology. Wm. Wood & Co., New York, 7th ed.
- BARNARD, J. W. 1938 Embryology of the mammalian tectum. A preliminary report. *Univ. (of Michigan) Hosp. Bul.*, vol. 4, p. 116.
- BARRIS, R. W., AND W. R. INGRAM 1934 Optic connections of the midbrain and thalamus. *Anat. Rec.*, vol. 58, suppl., p. 3.
- BARRIS, R. W., W. R. INGRAM AND S. W. RANSON 1935 Optic connections of the diencephalon and midbrain of the cat. *J. Comp. Neur.*, vol. 62, pp. 117-144.
- BECCARI, N. 1923 Il centro tegmentale interstiziale ed altre formazioni poco note nel mesencefalo e nel diencefalo di un rettile. *Arch. Ital. Anat. e Embr.*, vol. 20, pp. 560-619.
- VON BECHTEREW, W. 1899 Die Leitungsbahnen in Gehirn und Rückenmark. 2 Aufl., Leipzig.
- BERNHEIMER, S. 1896 Zur Kenntnis der Lokalisation in Kernegebiete des Oculomotorius. *Weiner klin. Wochenschr.*, Bd. 9, S. 73.
- 1897 Experimentell Studien zur Kenntnis der Innervation der inneren und ausseren von Oculomotorius versorgten Muskeln des Auges. *Archiv f. Ophthal.*, Bd. 44, S. 481-525.
- BOCHENEK, A. 1908 Ueber zentrale Endigung des Nervus opticus. *Bul. de l'Acad. Sci. de Cracovie, Classe de Sci. et Natur.*, pp. 91-95.
- BODIAN, DAVID 1939 Studies on the diencephalon of the Virginia opossum. I. The nuclear pattern in the adult. *J. Comp. Neur.*, vol. 71, pp. 259-323.
- 1940 Studies, etc. II. The fiber connections in normal and experimental material. *J. Comp. Neur.*, vol. 72, pp. 207-297.
- BRANDIS, F. 1895 Untersuchungen über das Gehirn der Vogel. III. Der Ursprung des N. trigeminus und der Augenmuskelnerven. *Arch. mikr. Anat.*, Bd. 44, S. 534.

- BROUWER, B. 1918 Klinisch-anatomische Untersuchungen über den Oculomotoriuskern. *Zeitschr. f. d. ges. Neur. u. Psychiat.*, Bd. 40, S. 152-193.
- 1927 Anatomical, phylogenetical and clinical studies on the central nervous system: The projection of the retina in the brain. *Herter Lectures*, 17, Williams & Wilkins Co., Baltimore.
- BROUWER, B., W. P. C. ZEEMAN AND A. W. M. HOUWER 1923 Experimentell-anatomische Untersuchungen über die Projektion der Retina auf die primären Opticuszentren. *Schweiz. Arch. f. Neur. u. Psychiat.*, Bd. 13, S. 118-138.
- BROWN, J. O. 1943 The nuclear pattern of the non-tectal portions of the midbrain and isthmus in the dog and cat. *J. Comp. Neur.*, vol. 78, pp. 365-405.
- BURKHOLDER, J. F. 1912 The anatomy of the brain. Engelhard & Co., Chicago, 2nd ed.
- CASTALDI, L. 1923 Studi sulla struttura e sullo sviluppo del mesencefalo. I. Ricerche in *Cavia cobaya*. *Arch. Ital. Anat. e Embr.*, vol. 20, pp. 23-225.
- 1924 Studi, etc. II. *Ibid.*, vol. 21, pp. 172-263.
- 1926 Studi, etc. III. *Ibid.*, vol. 23, pp. 481-609.
- CHRISTENSEN, K. 1927 The morphology of the brain of *Sphenodon*. *Univ. of Iowa Studies in Nat. Hist.*, vol. 12, no. 1.
- CHU, H. N. 1932 The cell masses of the diencephalon of the opossum, *Didelphis virginiana*. *Monogr. Nat. Res. Inst. of Psychol.*, Peiping, China, no. 2, 36 pp.
- CORBIN, K. B. 1940 Observations on the peripheral distribution of fibers arising in the mesencephalic nucleus of the fifth cranial nerve. *J. Comp. Neur.*, vol. 73, pp. 153-177.
- CORBIN, K. B., AND F. HARRISON 1938 Proprioceptive components of cranial nerves. The spinal accessory nerve. *J. Comp. Neur.*, vol. 69, pp. 315-328.
- 1940 Function of the mesencephalic root of the fifth cranial nerve. *J. Neurophysiol.*, vol. 3, pp. 423-435.
- 1941 The central pathway for the jaw-jerk. *Am. J. Physiol.*, vol. 135, pp. 439-445.
- 1942 Further attempts to trace the origin of afferent nerves to the extrinsic eye muscles. *J. Comp. Neur.*, vol. 77, pp. 187-190.
- CORBIN, K. B., F. HARRISON AND C. WIGGINTON 1941 Elicitation of the "Pseudomotor contracture" in the tongue by intramedullary stimulation. *Arch. Neur. and Psychiat.*, vol. 45, pp. 271-281.
- CORBIN, K. B., AND R. K. OLIVER 1942 The origin of the fibers to the grape-like endings in the insertion third of the extra-ocular muscles. *J. Comp. Neur.*, vol. 77, pp. 171-186.
- CRAIGIE, E. H. 1930 Studies on the brain of the kiwi (*Apteryx australis*). *J. Comp. Neur.*, vol. 49, pp. 223-357.
- 1932 The cell structure of the cerebral hemisphere of the hummingbird. *J. Comp. Neur.*, vol. 56, pp. 135-168.

- CROSBY, ELIZABETH C., AND RUSSELL T. WOODBURNE 1940 The comparative anatomy of the preoptic area and the hypothalamus. *Res. Publ. Ass. Nerv. Ment. Dis.*, vol. 20, pp. 52-169.
- 1943 a The nuclear pattern of the non-tectal portions of the mid-brain and isthmus in the armadillo. *J. Comp. Neur.*, vol. 78, pp. 191-211.
- 1943 b The nuclear pattern of the non-tectal portions of the mid brain and isthmus in the shrew and the bat. *J. Comp. Neur.*, vol. 78, pp. 253-288.
- 1943 c The nuclear pattern of the non-tectal portions of the mid-brain and isthmus in primates. *J. Comp. Neur.*, vol. 78, pp. 441-482.
- DARKSCHEWITSCH, L. 1885 Ueber die hintere Commissur des Gehirns. *Neur. Centralbl.*, Bd. 4, S. 100-101.
- 1886 Einige Bemerkungen über den Faserverlauf in der hinteren Commissur des Gehirns. *Neur. Centralbl.*, Bd. 5, S. 99-103.
- 1889 Ueber die oberen Kern des N. oculomotorius. *Arch. f. Anat. (u. Physiol.)*, S. 107-116.
- DAVENPORT, H. A., AND S. W. RANSON 1930 The red nucleus and adjacent cell groups. *Arch. Neur. and Psychiat.*, vol. 24, pp. 257-266.
- DEJERINE, J., AND M. ME 1901 Anatomie des centres nerveux. J. Reuff, Paris.
- DURWARD, A. 1932 Observations on the cell masses in the cerebral hemispheres of the New Zealand kiwi (*Apteryx australis*). *J. Anat.*, vol. 66, pp. 437-477.
- 1934 Some observations on the development of the corpus striatum of birds, with special reference to certain stages in the common sparrow (*Passer domesticus*). *J. Anat.*, vol. 68, pp. 492-499.
- DUVAL, M. 1878-1879 Recherches sur l'orgine réelle des nerves craniens. *J. de l'Anat. et de la Phys.*, vol. 14, p. 451 and vol. 15, p. 492.
- EDINGER, L. 1904 Vorlesungen über den Bau der nervösen Zentralorgane. 7th ed., vol. 1. F. C. W. Vogel, Leipzig.
- 1921 Einführung in die Lehre von Bau und den Verrichtungen des Nerven systems. F. C. W. Vogel, Leipzig.
- EDINGER, L., A. WALLEMBERG AND G. HOLMES 1903 Untersuchungen ueber die vergleichende Anatomie des Gehirns. 5. Das Vorderhirn der Vögel. *Abhandl. Senckenbergischen Naturf. Gesellsch.*, Bd. 20, H. 4, S. 343-426.
- FINLEY, K. H., AND S. COBB 1940 The capillary bed of the locus coeruleus. *J. Comp. Neur.*, vol. 73, pp. 49-58.
- FISKE, E. W. 1913 An elementary study of the brain based on the dissection of the brain of the sheep. The Macmillan Co., New York.
- FOIX, C., AND J. NICOLESCO 1925 Les noyaux gris centraux et la region mesencephalo-sous-optique. Masson et Cie, Paris.
- FOREL, A. 1877 Untersuchungen über die Haubenregion. *Arch. f. Psychiat.*, Bd. 7, S. 393-495.
- FOX, C. A. 1941 The mammillary peduncle and ventral tegmental nucleus in the cat. *J. Comp. Neur.*, vol. 75, pp. 411-425.
- FRANK, C. 1921 Ulteriori studii sopra i due nuovi nuclei nel mesencefalo dell'uomo. *Arch. gen. d. Neur., e. Psychiat.*, vol. 2, pp. 120-122.

- VON FRANKL-HOCHWART, L. 1902 Zur Kenntnis der Anatomie des Gehirns der Blindmaus (*Spalax typhlus*). Arb. neur. Inst. a. d. Wein. Univ., vol. 8, S. 190-220.
- FRIEDEMANN, M. 1912 Die Cytoarchitektonik des Zwischenhirns der Cereopitheken mit besonderer Berücksichtigung des Thalamus opticus. J. Psychol. u. Neur., Bd. 18, S. 310-378.
- FULTON, J. F. 1938 Physiology of the nervous system. Oxford Univ. Press.
- GANSER, S. 1882 Vergleichend-anatomische Studien über das Gehirn des Maulwurfs. Morph. Jahrb., Bd. 7, S. 591-725.
- GILLILAN, L. A. 1941 The connections of the basal optic root (posterior accessory optic tract) and its nucleus in various mammals. J. Comp. Neur., vol. 74, pp. 367-408.
- 1943 a The nuclear pattern of the non-tectal portions of the mid-brain and isthmus in rodents. J. Comp. Neur., vol. 78, pp. 213-251.
- 1943 b The nuclear pattern of the non-tectal portions of the mid-brain and isthmus in ungulates. J. Comp. Neur., vol. 78, pp. 289-364.
- GOLGI, C. 1894 Untersuchungen über den feineren Bau des centralen und peripherischen Nervensystems. G. Fischer, Jena.
- VON GUDDEN, B. 1881 Mittheilung über das Ganglion interpedunculare. Arch. f. Psychiat., Bd. 11, S. 424-427.
- 1889 Gesammelte und hinterlassene Abhandlungen (her. v. Graskey). Wiesbaden.
- GURDJIAN, E. S. 1927 The diencephalon of the albino rat. J. Comp. Neur., vol. 43, pp. 1-114.
- HATSCHEK, R. 1903 Zur Kenntnis des Pedunculus corporis mamillaris, des Ganglion tegmenti profundum und der dorso-ventralen Raphefaserung in der Haube. Obersteiner's Arb. a. d. Neur. Inst. an der Wein. Univ., Bd. 10, S. 81-103.
- 1907 Zur vergleichenden Anatomie des Nucleus ruber tegmenti. Ibid., Bd. 15, S. 89-136.
- HELD, H. 1893 Beiträge zur feineren Anatomie des Kleinhirns und des Hirnstammes. Arch. f. Anat. (u. Physiol.), S. 435-443.
- HENLE, J. 1871 Quoted from Duval, 1879.
- 1879 Handbuch der systematischen Anatomie des Menschen. Braunschweig, Bd. 3, Abt. 2, S. 252-255.
- HERRICK, C. JUDSON 1933 The amphibian forebrain. VI. Necturus. J. Comp. Neur., vol. 58, pp. 1-288.
- 1941 a Development of the optic nerves of *Amblystoma*. J. Comp. Neur., vol. 74, pp. 473-534.
- 1941 b The eyes and optic paths of the catfish, *Ameiurus*. J. Comp. Neur., vol. 75, pp. 255-286.
- HERRICK, C. JUDSON, AND ELIZABETH C. CROSBY 1918 A laboratory outline of neurology. W. B. Saunders Co., Philadelphia.
- HINES, M. 1929 The brain of *Ornithorhynchus anatinus*. Phil. Trans. Roy. Soc. London, B, vol. 217, pp. 155-278.

- HUBER, G. C., AND E. C. CROSBY 1926 On thalamic and tectal nuclei and fiber paths in the brain of the American alligator. *J. Comp. Neur.*, vol. 40, pp. 97-227.
- 1929 The nuclei and fiber paths of the avian diencephalon, with consideration of telencephalic and certain mesencephalic centers and connections. *J. Comp. Neur.*, vol. 48, pp. 1-225.
- 1933 a The reptilian optic tectum. *J. Comp. Neur.*, vol. 57, pp. 57-163.
- 1933 b A phylogenetic consideration of the optic tectum. *Proc. Nat. Acad. Sci.*, vol. 19, pp. 15-22.
- 1934 The influences of afferent paths on the cytoarchitectonic structure of the submammalian optic tectum. *Psych. en Neur. Bladen, Jaar. 1934*, pp. 459-474.
- 1943 A comparison of the mammalian and reptilian tecta. *J. Comp. Neur.*, vol. 78, pp. 133-168.
- HUMPHREY, T. 1936 The telencephalon of the bat. I. The noncortical nuclear masses and certain pertinent fiber connections. *J. Comp. Neur.*, vol. 65, pp. 603-711.
- HUNTER, J. I. 1923 The oculomotor nucleus of *Tarsius* and *Nycticebus*. *Brain*, vol. 46, p. 38.
- INGRAM, W. R., F. I. HANNETT AND S. W. RANSON 1932 The topography of the diencephalon of the cat. *J. Comp. Neur.*, vol. 55, pp. 333-394.
- INGRAM, W. R., AND S. W. RANSON 1934 The red nucleus. Its relation to postural tonus and righting reactions. *Arch. Neur. Psychiat.*, vol. 31, pp. 768-786.
- 1935 The nucleus of Darkschewitsch and the nucleus interstitialis in the brain of man. *J. Nerv. Ment. Dis.*, vol. 81, pp. 125-137.
- JACOBSON, L. 1909 Ueber die Kerne des menschlichen Hirnstammes. Anhang zu den Abh. Preuss. Akad. Wiss., Physik. Math. Kl. (Quoted from Ranson, '40).
- JOHNSTON, J. B. 1909 The radix mesencephalica trigemini. *J. Comp. Neur.*, vol. 19, pp. 593-644.
- KOHNSTAMM, O. 1900 Ueber die Koordinationskerne des Hirnstammes und die absteigenden Spinalbahnen. *Monats. f. Psychiat. u. Neur.*, Bd. 8, S. 261-293.
- 1910 Studien zur physiologischen Anatomie des Hirnstammes. III. *J. f. Psych. u. Neur.*, Bd. 17, S. 33.
- KOHNSTAMM, O., AND F. QUENSEL 1908 Ueber den Kern des hinteren Längsbündels, den roten Haubenkern und den Nucleus intratrigeminalis. *Neur. Centralbl.*, Bd. 27, S. 242.
- VON KÖLLIKER, A. 1896 Handbuch der Gewebelehre des Menschen. Leipzig.
- KOSAKA, K. 1912 Zur Frage der physiologischen Natur der zerebralen Trigeminiwurzel. *Folia Neurobiol.*, Bd. 6, S. 1-16.
- KOSAKA, K., AND K. HIRAIWA 1915 Zur Anatomie der Sehnervenbahnen und ihrer Zentren. *Folia Neurobiol.*, Bd. 9, S. 367-389.
- KUHLENBECK, H., AND R. N. MILLER 1942 The pretectal region of the rabbit's brain. *J. Comp. Neur.*, vol. 76, pp. 323-365.

- KURE, S. 1899 Die normale und pathologische Struktur der Zellen an der cerebralen Wurzel des Nervus trigeminus, die Kreuzungsfrage der letzteren und der motorischen Trigeminiwurzel. *Obersteiner's Arbeiten*, Bd. 6, S. 158.
- DE LANGE, S. J. 1913 Das Zwischenhirn und das Mittelhirn der Reptilien. *Folia Neurobiol.*, Bd. 7, S. 67-138.
- LE GROS CLARK, W. E. 1926 The mammalian oculomotor nucleus. *J. Anat.*, vol. 60, pp. 426-448.
- 1929 The thalamus of *Tupaia minor*. *J. Anat.*, vol. 63, pp. 177-206.
- 1930 The thalamus of *Tarsius*. *J. Anat.*, vol. 64, pp. 371-414.
- 1931 The brain of *Microcebus murinus*. *Proc. Zool. Soc. London* for 1931, pp. 463-486.
- 1932 An experimental study of thalamic connections in the rat. *Phil. Trans. Roy. Soc. London, B*, vol. 222, pp. 1-28.
- 1933 The medial geniculate body and the nucleus isthmi. *J. Anat.*, vol. 67, pp. 536-548.
- 1942 The cells of Meynert in the visual cortex of the monkey. *J. Anat.*, vol. 76, pp. 369-376.
- LEWY, F. H., R. A. DROFF AND F. C. GRANT 1938 Autonomic innervation of the face. II. An experimental study. *Arch. Neur. Psychiat.*, vol. 39, pp. 1238-1248.
- LOEPP, W. H. 1912 Ueber die zentralen Opticusendigung beim Kaninchen. *Anat. Anz.*, Bd. 40, S. 309.
- MAGOUN, H. W., AND S. W. RANSON 1935 a The afferent path of light reflex. A review of the literature. *Arch. Ophthal.*, vol. 13, pp. 862-874.
- 1935 b The central path of the light reflex. A study of the effect of lesions. *Arch. Ophthal.*, vol. 13, pp. 791-811.
- MAGOUN, H. W., S. W. RANSON AND L. L. MAYER 1935 The pupillary light reflex after lesions of the posterior commissure in the cat. *Am. J. Ophthal.*, vol. 18, pp. 624-630.
- MAHAIM, A. 1894 Recherches sur la structure anatomique du noyau rouge et ses connexions avec le pedoncule cerebral superieur. *Arch. Roy. Med., Bruxelles*, vol. 13, pp. 1-44.
- MALONE, E. F. 1913 Recognition of members of the somatic motor chain of nerve cells by means of a fundamental type of cell structure, and the distribution of such cells in certain regions of the mammalian brain. *Anat. Rec.*, vol. 7, pp. 67-82.
- MARBURG, O. 1903 Basale Opticuswurzel und Tractus peduncularis transversus. *Centralbl. f. Physiol.*, Bd. 17, S. 30.
- 1904 Mikroskopisch-topographischer Atlas des menschlichen Zentralnervensystems mit begleitendem Texte. F. Deuticke, Leipzig u. Wien.
- 1924 Handbuch der Neurologie des Ohres. Urban u. Schwarzenberg, Berlin u. Wien, Bd. 1, S. 290.
- MAY, O., AND V. HORSLEY 1910 The mesencephalic root of the fifth nerve. *Brain*, vol. 33, pp. 175-203.
- MESDAG, T. M. 1909 Bijdrage tot de ontwikkelingsgeschiedenis van de structuur der hersenen by het kipeembryo. Dissertation. Amsterdam.

- METTLER, FRED A. 1932 Connections of the auditory cortex of the cat. *J. Comp. Neur.*, vol. 55, pp. 139-183.
- 1942 *Neuroanatomy*. C. V. Mosby Co., St. Louis.
- MEYNERT, T. 1872 The brain of mammals. *Stricker's Manual of Histology*. Wm. Wood & Co., New York.
- MINGAZZINI, G. 1928 Medulla oblongata und Brücke. Das Mittelhirn. In G. von Möllendorf's *Handbuch der mikroskopische Anatomie des Menschen*, S. 579-673. J. Springer, Berlin.
- MOHNEY, J. B., M. W. MORGAN, JR., J. M. D. OLMSTED AND I. H. WAGMAN 1942 The pathway of sympathetic nerves to the ciliary muscles in the eye. *Am. J. Physiol.*, vol. 135, pp. 759-762.
- VON MONAKOW, C. 1910 Der rote Kern, die Haube und die Regio sub-thalamica bei einigen Säugetieren und beim Menschen. *Arb. a. d. hirnanat. Inst. in Zurich*, Bd. 4, S. 103-243.
- NEWMAN, H. H., AND J. I. PATTERSON 1910 Development of the nine-banded armadillo. *J. Morph.*, vol. 21, pp. 359-424.
- OBECHAIN, J. B. 1925 The brains of the South American marsupials, *Caenolestes* and *Orolestes*. *Field Mus. Nat. Hist. Pub.* 224, Zool. Series, vol. 14, pp. 175-232.
- OBERSTEINER, H. 1887, 1890 and 1901 The anatomy of the central nervous organs. P. Blakiston, Son & Co., Philadelphia.
- 1912 Anleitung beim Studium des Baues der nervösen Zentralorgane im gesunden und kranken Zustände. F. Deuticke, Leipzig u. Wien.
- O'LEARY, J. L. 1941 Structure of the area striata of the cat. *J. Comp. Neur.*, vol. 75, pp. 131-164.
- PALMGREN, A. 1921 Embryological and morphological studies on the midbrain and cerebellum of vertebrates. *Acta Zool.*, Bd. 2, S. 1-94.
- PANEGROSSI, G. 1904 Weiterer Beitrag zum Studium der Augenmuskelnervenkerne. *Monats. f. Psychiat. u. Neur.*, Bd. 16, S. 268-281, 344-376.
- PAPEZ, J. W. 1923 The mammillary peduncle, Marchi method. *Anat. Rec.*, vol. 25, p. 146.
- 1929 *Comparative neurology*. T. Y. Crowell Co., New York.
- 1932 The thalamic nuclei of the nine-banded armadillo (*Tatusia novemcincta*). *J. Comp. Neur.*, vol. 56, pp. 49-103.
- 1935 Thalamus of turtles and thalamic evolution. *J. Comp. Neur.*, vol. 61, pp. 433-475.
- PEARSON, A. 1943 The trochlear nerve in the human embryo. *J. Comp. Neur.*, vol. 78, pp. 29-43.
- PEKELSKY, A. 1922 Ueber die Kerne der Raphe und der benachbarten Anteile der retikulierten Substanz. *Obersteiner's Arb.*, Bd. 23, H. 3, S. 21-73.
- PERLIA, DR. 1889 Die Anatomie des Oculomotoriuscentrums beim Menschen. *Arch. f. Ophthal.*, Bd. 35, Abt. 4, S. 287-308.
- POLYAK, S. L. 1941 *The retina*. Univ. of Chicago Press.
- PREISIG, H. 1904 Le noyau rouge et le peduncle cerebelleux superieur. *J. f. Psychol. u. Neur.*, Bd. 3, S. 215-230.

- PROBST, M. 1901 Ueber den Verlauf der centralen Sehfasern (Rinden-Sehhügel-fasern) und deren Endigung im Zwischen- und Mittelhirne und über die Associations- und Commissurenfasern der Sehsphäre. *Archiv f. Psychiatrie*, Bd. 35, S. 22-43.
- QUAIN'S ANATOMY 1882 9th ed., vol. 2. Wm. Wood & Co., New York.
- RAMÓN Y CAJAL, S. 1896 Beitrag zum Studium der Medulla oblongata, der Kleinhirns und des Ursprungs der Gehirnnerven. Barth, Leipzig.
- 1909-1911 *Histologie du système nerveux de l'homme et des vertebres*. 2 vols. A. Maloine, Paris.
- RAMÓN, P. 1896 Estructura del encefalo del camaleon. *Rev. trimest. micrograf.*, vol. 1, pp. 46-82.
- RANSON, S. W. 1940 *The anatomy of the nervous system*. 6th ed. W. B. Saunders Co., Philadelphia.
- RANSON, S. W., AND H. W. MAGOUN 1933 The central path of the pupillo-constrictor reflex in response to light. *Arch. Neur. and Psychiat.*, vol. 30, pp. 1193-1202.
- RAUBER, A. 1893 *Lehrbuch der Anatomie des Menschen*. Bd. 2, Abt. 2. Besold, Leipzig.
- RIOCH, D. M. 1929 a Studies on the diencephalon of Carnivora. I. The nuclear configuration of the thalamus, epithalamus and hypothalamus of the dog and cat. *J. Comp. Neur.*, vol. 49, pp. 1-119.
- 1929 b Studies, etc. II. Certain nuclear configurations and fiber connections of the subthalamus and midbrain of the dog and cat. *J. Comp. Neur.*, vol. 49, pp. 121-153.
- 1931 Studies, etc. III. Certain myelinated-fiber connections of the diencephalon of the dog (*Canis familiaris*), cat (*Felis domestica*) and aevisa (*Crossarchus obscurus*). *J. Comp. Neur.*, vol. 53, pp. 319-388.
- ROSE, J. E. 1942 a The ontogenetic development of the rabbit's diencephalon. *J. Comp. Neur.*, vol. 77, pp. 61-129.
- 1942 b The thalamus of the sheep: cellular and fibrous structure and comparison with pig, rabbit and cat. *J. Comp. Neur.*, vol. 77, pp. 469-523.
- ROSE, M. 1914 Ueber die cytoarchitektonische Gliederung des Vorderhirns der Vögel. *J. f. Psychol. u. Neur.*, Bd. 21, S. 278-352.
- SANO, T. 1910 Beitrag zur vergleichenden Anatomie der Substantia nigra, des C. Luysii und der Zona incerta. *Monats. f. Psychiat. u. Neur.*, Bd. 27, S. 110-127.
- SCHNEIDER, A. J. 1928 The histology of the radix mesencephalica n. trigemini in the dog. *Anat. Rec.*, vol. 38, pp. 321-339.
- SCHROEDER, K. 1911 Der Faserverlauf im Vorderhirn des Huhnes. *J. f. Psychol. u. Neur.*, Bd. 18, S. 115-173.
- SCHWALBE, O. 1881 *Lehrbuch der Neurologie*. Besold, Erlangen.
- SHANKLIN, W. M. 1930 The central nervous system of Chameleon vulgaris. *Acta Zool.*, Bd. 11, S. 425-490.
- SHEININ, J. J. 1930 Typing of the cells of the mesencephalic nucleus of the trigeminal nerve in the dog, based on Nissl-granule arrangement. *J. Comp. Neur.*, vol. 50, pp. 109-131.

- SOLNITZKY, O. 1938 The thalamic nuclei of *Sus scrofa*. *J. Comp. Neur.*, vol. 69, pp. 121-169.
- 1939 The hypothalamus and subthalamus of *Sus scrofa*. *J. Comp. Neur.*, vol. 70, pp. 191-229.
- STENGEL, E. 1924 Vergleichend-anatomische Studien über die Kerne an der hinteren Kommissur und im Ursprungsgebiete des hinteren Langsbundels. *Arb. neur. Inst. a. d. Wein. Univ.*, Bd. 26, S. 419-454.
- STERZI, G. 1915 Anatomia del sistema nervoso centrale dell'uomo, vol. 2. A. Draghi, Padova.
- STIEDA, L. 1870 Studien über das centrale Nervensystem der Wirbeltiere. *Zeitsch. f. wiss. Zool.*, Bd. 20, S. 349, 367, 375.
- STILLING, B. 1846 *Disquisitiones de structura et functionibus cerebri*. Jena.
- TAMTHAI, B. 1943 The nuclear pattern of the non-tectal portions of the mid-brain and isthmus in the mink. *J. Comp. Neur.*, vol. 78, pp. 407-440.
- TARTUFERI, F. 1885 Sull'anatomia minuta dell'eminenze bigemine anteriori dell'uomo. *Arch. ital. per le mal. nerv.*, Milano, vol. 22, pp. 3-37.
- TERNI, T. 1912 Contributo alla conoscenza del nucleo mesencefalico del nervo trigemino (review). *Folia Neurobiol.*, Bd. 7, S. 195-197.
- THELANDER, H. E. 1924 The course and distribution of the radix mesencephalica trigemini in the cat. *J. Comp. Neur.*, vol. 37, pp. 207-220.
- TSAI, C. 1925 The optic tracts and centers of the opossum, *Didelphis virginiana*. *J. Comp. Neur.*, vol. 39, pp. 173-216.
- TSUCHIDA, U. 1906 Ueber die Ursprungskerne der Augenbewegungsnerven und über die mit diesen in Beziehung stehenden Bahnen im Mittel- und Zwischenhirn. *Arb. a. d. hirnanat. Inst. in Zürich*, Bd. 2, S. 1-205.
- VAN VALKENBURG, C. T. 1910 Nucleus facialis dorsalis, nucleus trigemini posterior, nucleus trochlearis posterior. *Proc. Kon. Akad. Wet. te Amsterdam, Sec. Sc.*, vol. 13, pt. 1, pp. 143-148.
- 1911 Zur vergleichenden Anatomie des mesencephalen Trigeminoanteils. *Folia Neurobiol.*, Bd. 5, S. 360.
- 1912 On the splitting of the nucleus trochlearis. *Proc. Kon. Akad. Wet. te Amsterdam, Sec. Sc.*, vol. 14, pt. 2, pp. 1023-1026.
- VERMEULEN, H. A. 1914 Das Kehlkopf Pfeifen beim Pferde. van Dishoek, Utrecht.
- WALKER, A. E. 1938 *The primate thalamus*. Univ. of Chicago Press.
- WALLENBERG, A. 1903 Der Ursprung des Tractus isthmo-striatus (oder bulbo-striatus) der Taube. *Neur. Centralbl.*, Bd. 22, S. 98.
- 1904 a Notiz zur Anatomie des Tractus peduncularis transversus beim Meerschweinchen. *Anat. Anz.*, S. 199-200.
- 1904 b 1904 c Neue Untersuchungen über den Hirnstamm der Taube. *Anat. Anz.*, Bd. 24, S. 357-369; Bd. 25, S. 526-528.
- WEINBERG, E. 1928 The mesencephalic root of the fifth nerve. *J. Comp. Neur.*, vol. 46, pp. 249-405.
- WESTPHAL, C. 1887 Ueber einen Fall von chronischer progressiver Lähmung der Augenmuskeln (Ophthalmoplegia externa) nebst Beschreibung von Ganglienzellengruppen im Bereiche des Oculomotoriuskerns. *Arch. f. Psychiat.*, Bd. 18, S. 846-869.

- WILLEMS, E. 1911 Les noyaux masticateur et mesencephalique du trijumeau chez le lapin (review by H. H. Donaldson). *J. Nerv. Ment. Dis.*, vol. 39, pp. 67-72.
- WINKLER, C., AND ADA POTTER 1911 An anatomical guide to the experimental researches on the rabbit's brain. Versluys, Amsterdam.
- 1914 An anatomical guide to the experimental researches on the cat's brain. Versluys, Amsterdam.
- WOODBURNE, R. T. 1936 A phylogenetic consideration of the primary and secondary centers and connections of the trigeminal complex in a series of vertebrates. *J. Comp. Neur.*, vol. 65, pp. 403-501.
- 1939 Certain phylogenetic anatomical relations of localizing significance for the mammalian central nervous system. *J. Comp. Neur.*, vol. 71, pp. 215-257.
- 1943 The nuclear pattern of the non-tectal portions of the midbrain and isthmus in the opossum. *J. Comp. Neur.*, vol. 78, pp. 169-190.
- ZERI, A. 1895 Sulle alterazioni dei centri nervosi nella tabe. *Riv. sper. di freniatria e med. legale*, vol. 21, p. 580.
- ZIEHEN, T. 1913, 1920 *Mikroskopische Anatomie des Gehirns. Handbuch der Anatomie des Menschen, Bardeleben, Bd. 4, Abt. 2, Erster Teil, 1913, Zweiter Teil, 1920.*
- ZWEIG, H. 1921 Studien zur vergleichenden Anatomie des zentralen Höhlengraus bei den Wirbeltieren. *Jahrb. f. Psych. u. Neur.*, Bd. 41, S. 18-38.

ABBREVIATIONS FOR ALL FIGURES

A. CUNEIFORM, cuneiform area	GR.CENT.P.VENT., pars ventralis of central gray
A.PRETECT., pretectal area	GR.PONT., pontine gray
A.VENT.TEG.TSAI, ventral tegmental area of Tsai	GR.PONT.TEG., pontine tegmental gray
A.VENT.TEG. OF TSAI, ventral tegmental area of Tsai	GR.TRAPEZOID, trapezoid gray
AQ, aqueduct	K, interstitial nucleus of commissure of Forel
ANSA LENT., ansa lenticularis	LEM.LAT., lateral lemniscus
BR.CONJ., brachium conjunctivum	LEM.MED., medial lemniscus
BR.PONT., brachium pontis	LOC.COERUL., locus coeruleus
C, caudal continuation of stratum album profundum over inferior colliculus	M, large-celled nucleus of the optic tract
CAP.COL.INF., capsule of inferior colliculus	N.ANGUST. (ZIEHEN), nucleus angustiae of Ziehen
CAP.N.GEN.MED., capsule of medial geniculate nucleus	N.ANNUL.F.L.M., annular nucleus of medial longitudinal fasciculus
CAP.N.RUB., capsule of red nucleus	N.ANNULARIS, annular nucleus of medial longitudinal fasciculus
CEREB., cerebellum	N.CAUD.VENT.LEM.LAT., caudal ventral nucleus of lateral lemniscus
COL.INF., inferior colliculus	N.CAUD.VENT.LEM.LAT.P.INTRAF., pars intrafascicularis of caudal ventral nucleus of lateral lemniscus
COL.SUP., superior colliculus	N.CAUD.VENT.LEM.LAT.P.LAT., pars lateralis of caudal ventral nucleus of lateral lemniscus
COM.ANT., anterior commissure	N.CAUD.VENT.LEM.LAT.P.ROST.DOR., pars rostradorsalis of caudal ventral nucleus of lateral lemniscus
COM.COL.INF., commissure of inferior colliculus	N.CAUD.VENT.LEM.LAT.P.VENTROMED., pars ventromedialis of caudal ventral nucleus of lateral lemniscus
COM.FOREL, commissure of Forel	N.CENT.COL.INF., central nucleus of inferior colliculus
COM.HAB., habenular commissure	N.CENT.PERLIA, central nucleus of Perlia
COM.POST., posterior commissure	N.CENT.SUBCOM., pars centralis subcommissuralis of nucleus of posterior commissure
CORP.MAM., mammillary body	N.CENT.SUBCOM. (KUHLENBECK-MILLER), nucleus centralis subcommissuralis commissurae posterioris of Kuhlenbeck and Miller
DEC.BRACH.CONJ., decussation of brachium conjunctivum	N.COM.POST., nucleus of posterior commissure
DEC.IV, decussation of trochlear nerve	N.DARKSCH., nucleus of Darkschewitsch
DEC.P.C.S., decussation of superior cerebellar peduncle	N.DORS.LEM.LAT., dorsal nucleus of lateral lemniscus
DEC.SUPRAMAM., supramammillary decussation	
DEC.TEG.DORS., dorsal tegmental decussation	
DEC.TEG.VENT., ventral tegmental decussation	
F.L.M., medial longitudinal fasciculus	
FOR., fornix	
FPC., posterior column of fornix	
GP., pineal gland	
GR.CENT., central gray	
GR.CENT.P.DORS., pars dorsalis of central gray	
GR.CENT.P.LAT., pars lateralis of central gray	

- N.DORS.LEM.LAT.P.CAUD.DOR., pars caudo-dorsalis of dorsal nucleus of lateral lemniscus
- N.DORS.LEM.LAT.P.ROST.DOR., pars rostro-dorsalis of dorsal nucleus of lateral lemniscus
- N.DORS.RAPHE, dorsal nucleus of raphé
- N.DORS.RAPHE (C), central portion of dorsal nucleus of raphé
- N.DORS.RAPHE (D), dorsal portion of dorsal nucleus of raphé
- N.DORS.RAPHE (L), lateral wing of dorsal nucleus of raphé
- N.DORS.RAPHE (V), ventral portion of dorsal nucleus of raphé
- N.DORS.TEG., dorsal tegmental nucleus
- N.ED.WEST., Edinger-Westphal nucleus
- N.ED.WEST.P.CAUD., pars caudalis of Edinger-Westphal nucleus
- N.ED.WEST.P.ROST., pars rostralis of Edinger-Westphal nucleus
- N.GEN.LAT., lateral geniculate nucleus
- N.GEN.MED., medial geniculate nucleus
- N.GEN.MED.P.DORS., pars dorsalis of medial geniculate nucleus
- N.HAB.LAT., lateral habenular nucleus
- N.INTERPED., interpeduncular nucleus
- N.INTERPED.P.LAT., pars lateralis of interpeduncular nucleus
- N.INTERPED.P.MED., pars medialis of interpeduncular nucleus
- N.INTERST.COM.FOREL, interstitial nucleus of commissure of Forel
- N.INTERST.COM.POST., pars intracommissuralis of nucleus of posterior commissure
- N.INTERST.DEC.SUPRAMAM., interstitial nucleus of supramammillary decussation
- N.INTERST.DEC.TEG.VENT., interstitial nucleus of ventral tegmental decussation
- N.INTERST.F.L.M., interstitial nucleus of medial longitudinal fasciculus
- N.INTERST.MAG.COM.POST. (KUHLENBECK-MILLER), nucleus interstitialis magnocellularis commissurae posterioris of Kuhlenbeck and Miller
- N.INTERST.PRIN.COM.POST. (KUHLENBECK-MILLER), nucleus interstitialis principalis commissurae posterioris of Kuhlenbeck and Miller
- N.INTERST.TEG.TSAI, interstitial tegmental nucleus of Tsai
- N.INTRACOM.COM.POST., pars intracommissuralis of nucleus of posterior commissure
- N.LAT.AN.AQ. (ZIEHEN), nucleus lateralis annuli aqueductus of Ziehen
- N.LAT.THAL., lateral nucleus of dorsal thalamus
- N.LATERODORS.TEG., laterodorsal tegmental nucleus
- N.LIN.CAUD., caudal linear nucleus
- N.LIN.INTERMED., intermediate (central) linear nucleus
- N.LIN.ROST., rostral linear nucleus
- N.LOC.COERUL., nucleus of locus coeruleus
- N.M.V, motor nucleus of V
- N.MAG.COM.POST., pars magnocellularis of nucleus of posterior commissure
- N.MAR.P.C.S., marginal nucleus of superior cerebellar peduncle
- N.MED.AN.AQ. (ZIEHEN), nucleus medianus annuli aqueductus of Ziehen
- N.MED.ANT., nucleus medianus anterior
- N.MED.PROF., nucleus medialis profundus
- N.MED.PROF.(N.VENT.TEG.V.GUDDEN), nucleus medialis profundus (central tegmental nucleus of von Gudden)
- N.MEDIANUS RAPHE, nucleus medianus of raphé
- N.MES.PROF., deep mesencephalic gray
- N.MES.PROF.P.DORS.(CAUD.), caudal portion of pars dorsalis of deep mesencephalic gray
- N.MES.PROF.P.DORS.(ROST.), rostral portion of pars dorsalis of deep mesencephalic gray
- N.MES.PROF.P.LAT., pars lateralis of deep mesencephalic gray
- N.MES.PROF.P.VENT., pars ventralis of deep mesencephalic gray
- N.MIN., nucleus minimus
- NN.OC., oculomotor nerve roots

- NN.TROCH., trochlear nerve roots
 N.OC., oculomotor nucleus
 N.OC.DORS.LAT., dorsolateral portion of oculomotor nucleus
 N.OC.VENT.MED., ventromedial portion of oculomotor nucleus
 N.OC.VENT.MED.P.MED., pars medialis of ventromedial portion of oculomotor nucleus
 N.OC.VENTROMED., ventromedial portion of oculomotor nucleus
 N.OC.VENTROMED.P.LAT., pars lateralis of ventromedial portion of oculomotor nucleus
 N.PARAMED.DORS. (ZIEHEN), nucleus paramedianus dorsalis of Ziehen
 N.PARVICELL.AN.AQ. (ZIEHEN), nucleus parvicellularis annuli aqueductus of Ziehen
 N.PED.MAM., nucleus of mammillary peduncle
 N.POST.THAL., posterior nucleus of dorsal thalamus
 N.PRETECT., pretectal nucleus
 N.PRETECT.P.CAUD., pars caudalis of pretectal nucleus
 N.R.OP.BAS., nucleus of basal optic root
 N.R.MES.V., nucleus of mesencephalic root of V
 N.ROST.VENT.LEM.LAT., rostral ventral nucleus of lateral lemniscus
 N.RUB., red nucleus
 N.RUB.P.MAG., pars magnocellularis of red nucleus
 N.RUB.P.PARV., pars parvocellularis of red nucleus
 N.SUBTHAL., subthalamic nucleus of ventral thalamus
 N.SUPRAGENIC., supragenieulate nucleus
 N.SUPRAMAM., supramammillary nucleus
 N.SUPRATROCH.SUB.GRIS. (JACOBSON), nucleus supratrochlearis substantiae griseae of Jacobsohn
 N.TR.OP., large-celled nucleus of optic tract
 N.TR.OP.B., nucleus of basal optic root
 N.TROCH., trochlear nucleus
 N.TROCH.POST., posterior trochlear nucleus
 N.VENT.LEM.LAT., ventral nucleus of lateral lemniscus
 N.VENT.TEG., ventral tegmental nucleus
 O.SUBCOM., subcommissural organ
 P, fusion of ventromedial oculomotor nuclei at midline
 P.C.S., superior cerebellar peduncle
 PED.CER., cerebral peduncle
 PED.CEREB.SUP., superior cerebellar peduncle
 PED.COLINF., peduncle of inferior colliculus
 PED.COL.SUP., peduncle of superior colliculus
 PED.MAM., mammillary peduncle
 PONS, pons
 PONT.RAPHE, pontine raphé
 Q, rostral extension of dorsal nucleus of raphé
 R.OC., oculomotor nerve roots
 STR.ALB.CENT., stratum album centrale
 STR.ALB.INTERMED., stratum album intermediale
 STR.ALB.PROF., stratum album profundum
 STR.FIB.INTERMED., stratum fibrosum intermediale
 STR.GR.CENT., stratum griseum centrale
 STR.GR.ET FIB.PERIVENT., stratum griseum et fibrosum periventriculare
 STR.GR.ET FIB.SUPERF., stratum griseum et fibrosum superficiale
 STR.GR.INTERMED., stratum griseum intermediale
 STR.GR.PERIVENT., stratum griseum periventriculare
 STR.GR.PROF., stratum griseum profundum
 STR.GR.SUPERF., stratum griseum superficiale
 STR.OPT., stratum opticum
 STR.ZON., stratum zonale
 SUB.NIG.P.COMP., pars compacta of substantia nigra
 SUB.NIG.P.LAT., pars lateralis of substantia nigra
 SUB.NIG.P.RET., pars reticulata of substantia nigra
 SUL.MED., sulcus medius
 SUL.HYP., sulcus hypothalamicus

TOR.SEMICIRC., torus semicircularis	x, nucleus x; see Gillilan, '43 b
TR.CORT.SP., cortico-spinal tract	z., specialized ventrolateral portion of
TR.HAB.PED., habenulo-peduncular tract	pars lateralis of central gray
TR.OP., optic tract	Z.INCERTA, zona incerta
v, ventricle	

